2020
Global Natural Disaster Assessment Report

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Ministry of Emergency Management - Ministry of Education

National Disaster Reduction Center of China,
Ministry of Emergency Management

International Federation of Red Cross
and Red Crescent Societies

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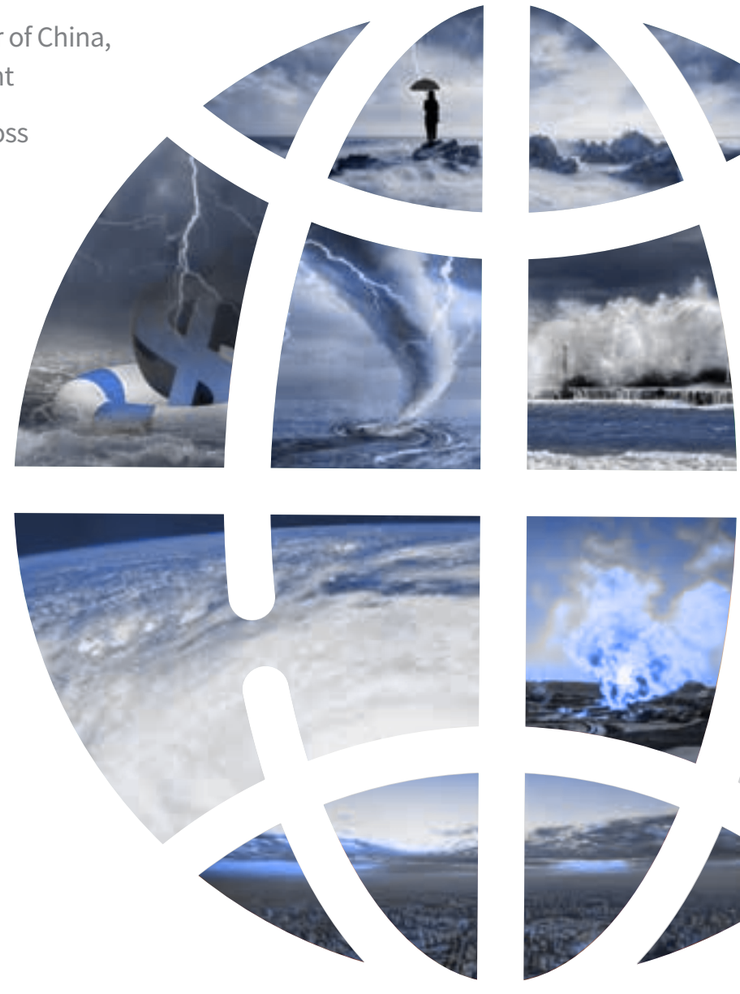

Executive Summary

Compared to the average over the last 30 years (1990-2019), the occurrence and intensity of global natural disasters were generally at a lower level in 2020. Major natural disasters in 2020 were 4% less in frequency, 73% lower in deaths, 50% less in the population affected and 29% more in direct economic losses. In 2020, the frequency of extreme temperatures around the world was low, but the number of deaths from such events was the most, reaching 6343; flood disasters were the most frequent, 43% more than historic levels and causing 6171 deaths, but the flood-related deaths were 7% less than the historical average; the direct economic losses caused by storm disasters were large, reaching USD 93.2 billion and 64% more than historic levels; there were fewer strong earthquakes, with relatively small disaster losses; the number of deaths from wildfires decreased, but the direct economic losses were 172% higher than those in history. Regionally, Asia has seen the highest frequency of natural disasters in 2020, followed by Africa; among all continents, Europe has had the largest number of deaths due to disasters, followed by Asia; North America has seen the highest economic losses due to disasters, followed by Asia; compared with developed countries, developing countries were more severely affected by disasters, mostly floods and storms. In 2020, deaths from natural disasters in China were at a lower level in the world, and the proportion of direct economic losses in GDP was in the upper middle level, which were basically consistent with the level of its economic development. The flood losses in China were higher than those from other disasters, which accounted for a large proportion of the global flood losses.

Flood disasters were the major natural disasters affecting the world in 2020. The results of analysis of historical disaster losses show that in addition to single loss, we should also pay attention to cumulative loss in research and practice of flood risk management; in the future, while strengthening the prevention and control of flood events of medium intensity and above, we shall also pay closer attention to small and frequent flood disaster events so as to reduce flood-related fatalities.

By sorting out the flood disaster losses in China from 2009 to 2018, focusing on the flood disasters in southern China that occurred in the summer of 2020, and comparing them with typical flood events in history, the report finds that China has successfully mitigated major flood losses through a series of measures of integrated flood disaster risk reduction.

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1 Overview of global natural disasters in 2020

A total of 313 major natural disasters (excluding epidemic diseases)[1] occurred worldwide in 2020, affecting 123 countries and regions. Among all these disasters, 193 were caused by floods, with the highest frequency, accounting for 61.66% of the total; 69 caused by storms (typhoons, hurricanes), accounting for 22.04%; 19 caused by landslides, accounting for 6.07%; 14 by earthquakes, accounting for 4.47%; 7 by droughts, accounting for 2.24%; 6 by forest and grassland fires, accounting for 1.92%; 3 by volcanic eruptions, accounting for 0.96%; 2 by extreme temperatures, accounting for 0.64% (Table 1 and Figure 1a).

Table 1 The frequency and losses of natural disasters worldwide in 2020

Type of disaster	Frequency (time)/%	Deaths (persons)/%	Population affected (tens of thousands)/%	Direct economic losses (USD 1 million)/%
Flood	193/61.66	6171/40.92	3321.56/33.56	51456.66/29.72
Storm	69/22.04	1742/11.55	4547.08/45.95	93225.89/53.85
Landslide	19/6.07	514/3.41	17.98/0.18	130.00/0.08
Earthquake	14/4.47	196/1.30	37.61/0.38	9582.50/5.53
Drought	7/2.24	45/0.30	1877.52/18.97	7500.00/4.33
Wildfire	6/1.92	70/0.46	14.35/0.14	11172.00/6.45
Volcanic eruption	3/0.96	1/0.01	77.58/0.78	66.00/0.04
Extreme temperature	2/0.64	6343/42.06	3.00/0.03	0/0
Total	313/100	15082/100	9896.67/100	173133.05/100

1.Note: The global natural disaster data covered in this report come from the EM-DAT database; the time period is January 1, 2020-December 31, 2020.

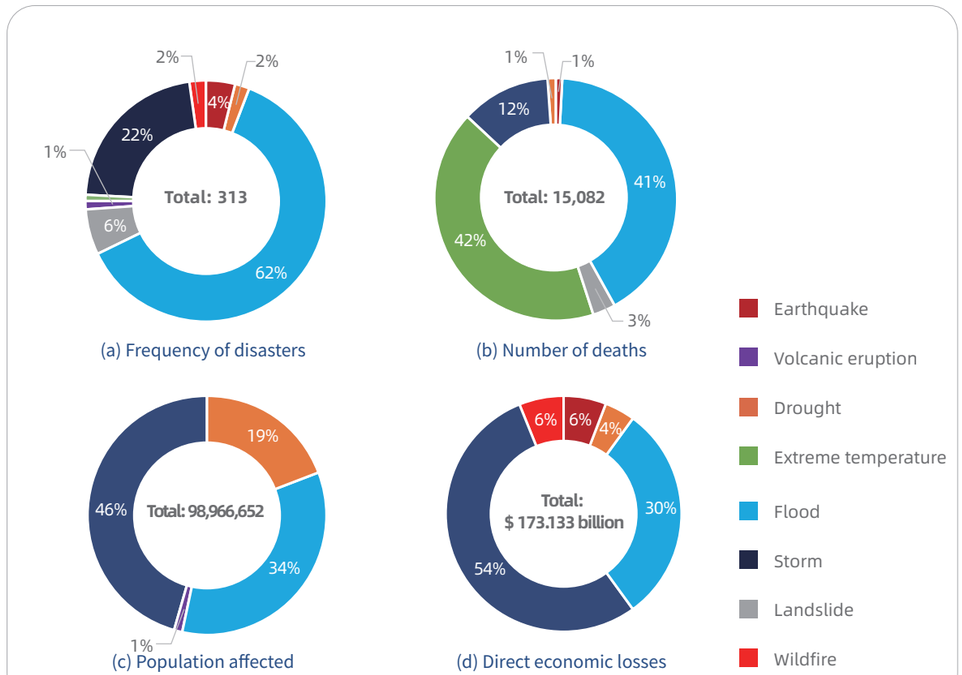


Figure 1 Breakdown of frequency and losses per disaster type worldwide in 2020

A total of 15,082 people were killed by natural disasters worldwide in 2020. Extreme temperatures caused the largest number of deaths, reaching 6,343 people, accounting for 42.06%; followed by floods with 6,171 people, accounting for 40.92%; storms with 1,742 people, accounting for 11.55%; landslides with 514 people, accounting for 3.41%; earthquakes with 196 people, accounting for 1.30%; wildfires with 70 people, accounting for 0.46%; volcanic eruptions with 1person, accounting for 0.01%.

A total of 98.9667million people were affected by natural disasters globally in 2020, of whom 45.95% were affected by storms, reaching 45.4708 million people, accounting for the largest proportion of the total; 33.56% by floods, reaching 33.2156 million people; 18.97% by droughts, reaching 18.7752 million people; less than 2.00% were affected by other types of disasters.

A total of USD 173.133 billion in direct economic losses were caused by natural disasters worldwide in 2020, of which 53.85% were caused by storms, reaching USD 93.226 billion, accounting for the most portion of the total amount; 29.72% were caused by floods, reaching USD 51.457 billion; 6.45% caused by wildfires, reaching USD 11.172 billion; 5.53% by earthquakes, reaching USD 9.583 billion; 4.33% by droughts, reaching USD7.500 billion; less than 0.20% were caused by other disasters.

2 Characteristics of global natural disasters in 2020

2.1 The overall economic losses from natural disasters were large, but the deaths and the number of people affected by the disasters have decreased

In 2020, a total of 313 major natural disasters occurred worldwide, killing 15,082 people, affecting 98.9667 million people, and causing direct economic losses of USD 173.133 billion. Compared with the average for the past 30 years (1990-2019), the frequency of major natural disasters was 4% less in 2020, the death toll was 73% less, the affected population was 50% less, and the direct economic loss was 29% higher. Compared with the average for the past 10 years (2010-2019), the frequency of major natural disasters was 6% less in 2020, the number of deaths was 67% less, the number of people affected was 41% less, and the direct economic loss was 2% less (Figure 2).

Although the year 2020 has witnessed several catastrophic natural disasters, they were generally less severe than those in the past 10 years and 30 years, which is the main reason for the overall low level of natural disasters in 2020. There were two natural disasters with more than 1,000 deaths each time globally in 2020, which was lower than the annual average for the past 30 years, and there were no natural disasters with more than 10,000 deaths (while 20 such natural disasters were recorded in the past 30 years). In 2020, there were four natural disasters with direct economic losses of more than USD 10 billion each time worldwide, slightly higher than the annual average for the past 30 years, but there were no disasters that caused direct economic losses exceeding USD 50 billion. There have been 8 disasters with direct economic losses exceeding USD 50 billion at a time in the past 30 years, 3 of which caused losses valued at over USD 100 billion.

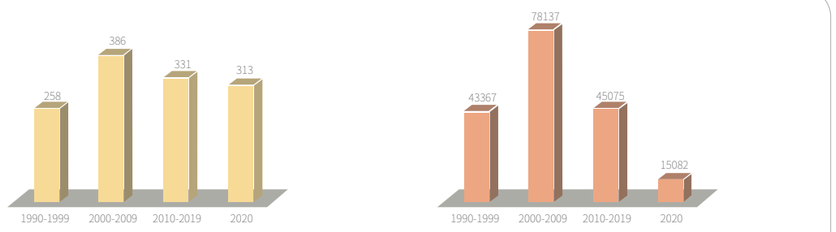
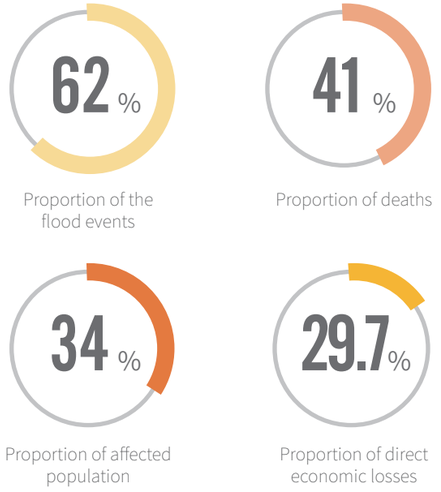


Figure 2 Average annual global natural disaster losses, 1990-2019 vs. 2020

(Note: The direct economic losses from 1990 to 2019 are measured at 2019 price level, and those of 2020 are measured at the current year price level)

2.2 Flood disasters were the most frequent and caused many deaths

There were 193 major flood disasters in 2020, accounting for more than 60% of the total number of major disasters of the year; 6,171 deaths were caused by flood disasters, accounting for about 41% of the total deaths; 33.22 million people were affected, accounting for about 34%, an increase from 29.63 million in 2019; the direct economic losses were nearly USD 51.5 billion. Compared with the average for the past 30 years (1990-2019), the frequency of flood disasters increased by 43% in 2020, the number of deaths due to disasters was 7% less, people affected were 67% fewer, and the direct economic losses were 59% more. Compared with the average for the past 10 years (2010-2019), the frequency of flood disasters increased by 33% in 2020, and the number of deaths due to disasters was 22% more, people affected were 50% fewer, and the direct economic losses were 23% higher (Figure 3). There was one flood disaster with more than 1,000 deaths in 2020. India and other Asian countries have suffered from severe floods, with thousands of lives lost in floods or heavy rain during the monsoon period.



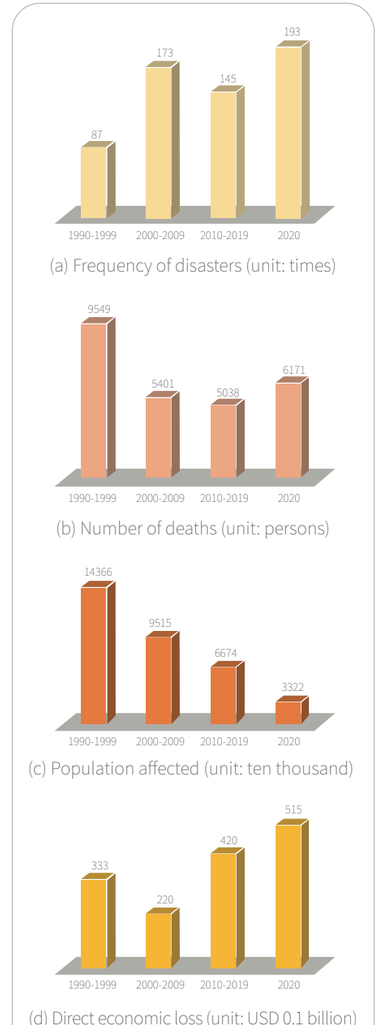


Figure 3 Global average annual flood disaster losses, 1990-2019 vs. 2020

(Note: The direct economic losses from 1990 to 2019 are measured at 2019 price level, and those of 2020 are measured at the current year price level)

2.3 Storm disasters resulted in large direct economic losses, with a greater affected population

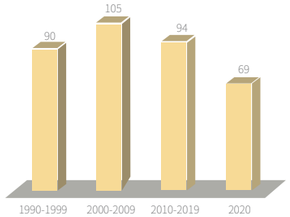
There were 69 major storm disasters in 2020, accounting for about 22% of the total number of major disasters; storm disasters caused 1,742 deaths (12%) and affected 45.47 million people (46%); the direct economic losses amounted to USD 93.2 billion, accounting for 54%. Compared with the average for the past 30 years (1990-2019), the frequency of storm disasters was 28% less in 2020, the number of deaths was 87% less, the affected population increased by 46%, and the direct economic losses were 64% higher. Compared with the average for the past 10 years (2010-2019), the frequency of storm disasters was 27% less in 2020, the number of deaths was 36% less, the affected population increased by 45%, and the direct economic losses were 24% higher (Figure 4).

Proportion of the storm events

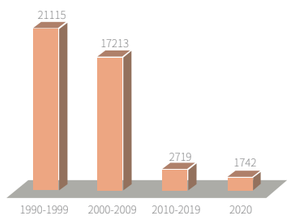
Proportion of deaths

Proportion of affected population

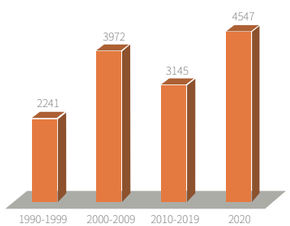
Proportion of direct economic losses



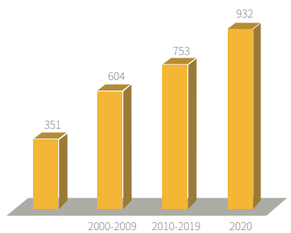
(a) Frequency of disasters (unit: times)



(b) Number of deaths (unit: persons)



(c) Population affected (unit: ten thousand)



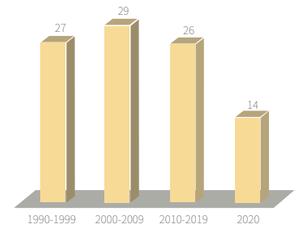
(d) Direct economic loss (unit: USD 0.1 billion)

Figure 4 Global average annual losses from storm disasters, 1990-2019 vs. 2020

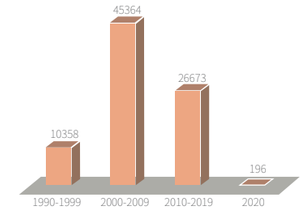
(Note: The direct economic losses from 1990 to 2019 are measured at 2019 price level, and those of 2020 are measured at the current year price level)

2.4 Weaker seismic activities and smaller earthquake disaster losses

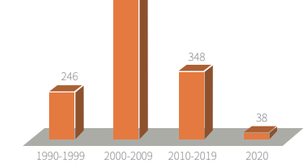
There were 14 major earthquake disasters worldwide in 2020, accounting for about 4% of the total number of major disasters; these earthquakes caused 196 deaths (approximately 1%); less than 1% of the people were affected by the disasters; the direct economic losses accounted for about 6%. Compared with the average for the past 30 years (1990-2019), the frequency of earthquake disasters reduced by 49% in 2020, deaths due to disasters were 99% fewer, the number of affected people was 92% less, and the direct economic losses were 70% lower. Compared with the average for the past 10 years (2010-2019), the frequency of earthquake disasters was 46% lower in 2020, deaths due to disasters were 99% fewer, the number of affected people was 89% less, and the direct economic losses were 77% lower (Figure 5). There have been no earthquakes of magnitude 8 or above, and no secondary disasters caused by earthquakes, such as large-scale tsunamis, have occurred, which is also one of the important reasons for the relatively small losses from earthquakes in 2020.



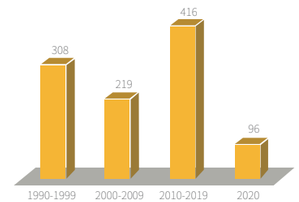
(a) Frequency of disasters (unit: times)



(b) Number of deaths (unit: persons)



(c) Population affected (unit: ten thousand)



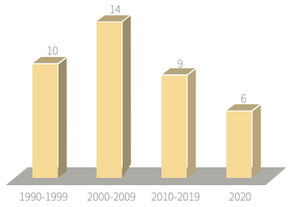
(d) Direct economic loss (unit: USD 0.1 billion)

Figure 5 Average annual global earthquake disaster losses, 1990-2019 vs. 2020

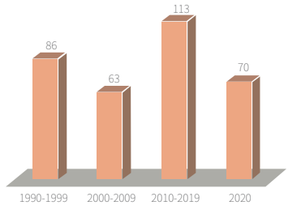
(Note: The direct economic losses from 1990 to 2019 are measured at 2019 price level, and those of 2020 are measured at the current year price level)

2.5 The number of deaths from wildfires has decreased, but the direct economic losses have increased

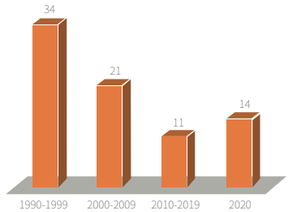
There were 6 wildfire disasters that caused large losses in 2020, which was lower than the level of recent years (an average of 11 times a year for the past 30 years and an average of 9 times a year for the past 10 years). Compared with the average for the past 30 years, the number of global deaths due to wildfire disasters was 20% lower in 2020, the number of affected people was 36% less, and the direct economic losses increased by 172%. Compared with the average for the past 10 years, the global deaths due to wildfire disasters reduced by 38% in 2020, the affected population increased by 27%, and the direct economic losses increased by 75% (Figure 6). Wildfires in California, U.S. in August 2020 caused direct economic losses of USD 11 billion, which leads to the total direct economic losses from wildfires in 2020 higher than the annual average for the past 30 years and the past 10 years respectively.



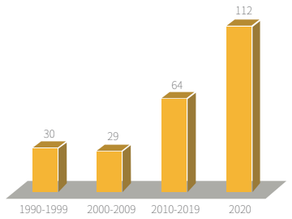
(a) Frequency of disasters (unit: times)



(b) Number of deaths (unit: persons)



(c) Population affected (unit: ten thousand)



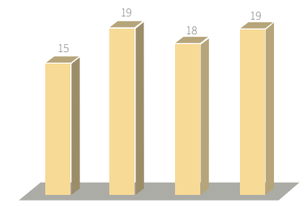
(d) Direct economic loss (unit: USD 0.1 billion)

Figure 6 Global average annual losses from wildfire disasters, 1990-2019 vs. 2020

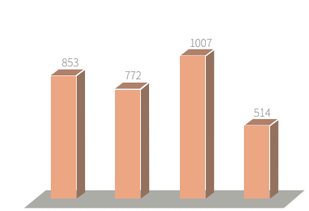
(Note: The direct economic losses from 1990 to 2019 are measured at 2019 price level, and those of 2020 are measured at the current year price level)

2.6 Frequent landslide disasters, with moderate losses

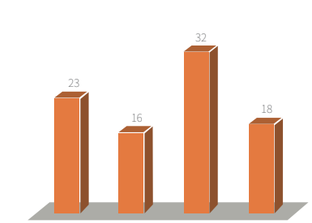
A total of 19 landslide disasters occurred in 2020, slightly higher than the level of recent years (an average of 17 times a year for the past 30 years and an average of 18 times a year for the past 10 years). Compared with the average for the past 30 years (1990-2019), the number of deaths from landslide disasters was 41% less, the affected people were 23% fewer, and the direct economic losses were 63% lower. Compared with the average for the past 10 years (2010-2019), landslide deaths in 2020 were 49% fewer, people affected were 44% fewer, and the direct economic losses were 66% lower (Figure 7).



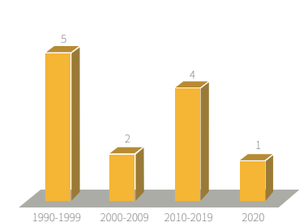
(a) Frequency of disasters (unit: times)



(b) Number of deaths (unit: persons)



(c) Population affected (unit: ten thousand)



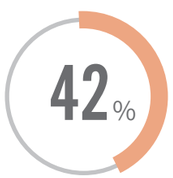
(d) Direct economic loss (unit: USD 0.1 billion)

Figure 7 Global annual average losses from landslide disasters, 1990 to 2019 vs. 2020

(Note: The direct economic losses from 1990 to 2019 are measured at 2019 price level, and those of 2020 are measured at the current year price level)

2.7 Extreme temperatures became less frequent, but caused great deaths

A total of two extreme temperature events occurred in 2020. However, the disasters caused 6,343 deaths, accounting for 42% of the total. Compared with the average for the past 30 years, the frequency of global extreme temperatures was 88% less in 2020, the number of deaths was 9% higher, and the affected people were 99% fewer. Compared with the average for the past 10 years, the frequency of global extreme temperatures was 90% less in 2020, the death toll was 14% lower and the affected people were 97% fewer (Figure 8). In June 2020, an extreme high temperature disaster occurred in Europe, which lasted for nearly three months and resulted in 6,340 deaths. This incident leads to deaths attributed to extreme temperatures increasing in 2020.



Proportion of deaths

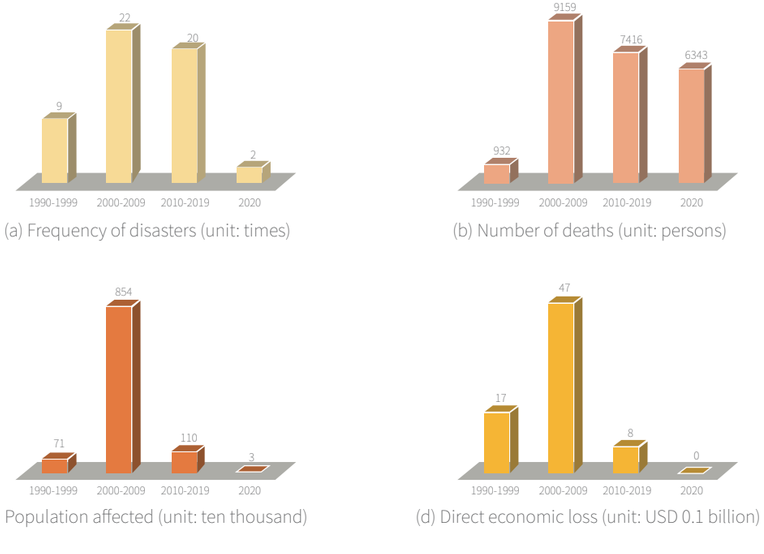


Figure 8 Global annual average losses from extreme temperatures, 1990 to 2019 vs. 2020

(Note: The direct economic losses from 1990 to 2019 are measured at 2019 price level, and those of 2020 are measured at the current year price level)

3 Global patterns of natural disasters in 2020

3.1 Spatial pattern of global natural disasters in 2020

In 2020, the main types of natural disasters occurring globally were meteorological and hydrological disasters and geological disasters, including floods, storms and earthquakes (Figure 9). Floods were the most frequent of all types of natural disasters around the world in 2020. There were 193 floods in total that cumulatively affected 201 countries, distributed between 40°N and 40°S, mainly in South Asia, South America and Africa; Storms were the second with a total of 69 occurrences, which cumulatively affected 126 countries, mainly distributed in Europe, South Asia and southern North America; landslides were the geological disasters with the highest frequency in 2020, a total of 19 times, mainly distributed in southwestern China, Southeast Asia, Central America and eastern Africa; 14 earthquakes occurred, mainly in the Middle East, Europe, Southeast Asia, and northwestern South America; seven drought disasters occurred, mainly in western and southern Africa; three volcanic disasters occurred, of which one was in South America and the other two were in Southeast Asia; six wildfires occurred, cumulatively affecting eight countries, mainly in North America, Southwest China and the Middle East; two extreme temperature disasters occurred, including one extreme high temperature in Europe, cumulatively affecting three countries, and one extreme low temperature in West Asia.

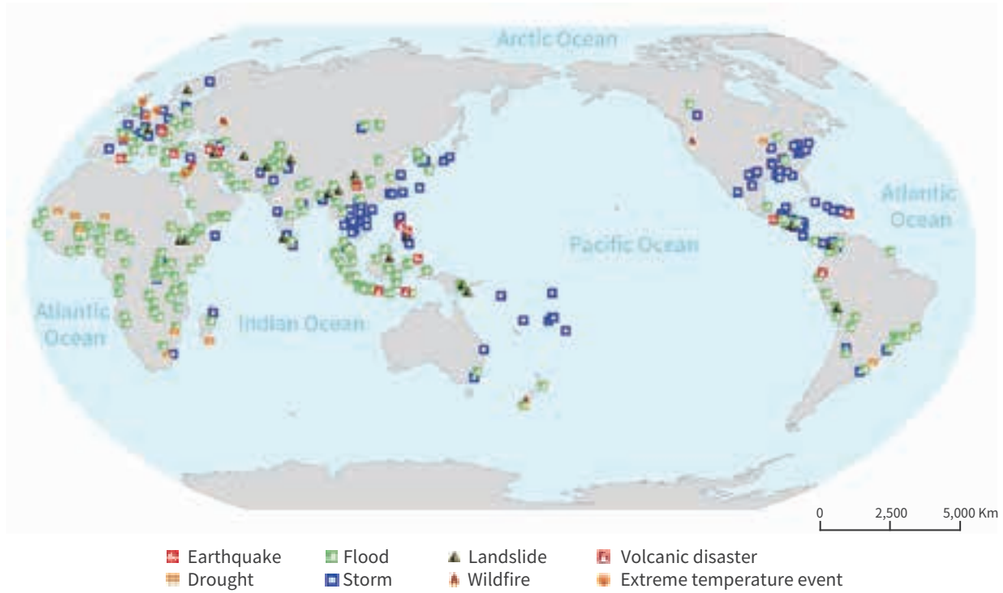


Figure 9 Global spatial pattern of natural disasters, 2020

3.2 Natural disasters by continent in 2020

Figure 10 shows the statistical results of the frequency of natural disasters, the number of deaths attributed to disasters, and the direct economic losses in all continents from January 1 to December 31, 2020. Among the 313 natural disaster events included in the statistics, Asia had the largest number of disaster events with a total of 135, accounting for 43.13%; followed by Africa, North America and South America, with 75 times (accounting for 23.96%), 39 times (accounting for 12.46%) and 28 times (accounting for 8.95%) respectively. In terms of the number of deaths attributed to disasters, Europe had the largest number with 6,464 deaths in total, accounting for 42.86% of the global total, followed by Asia, with 6,042 deaths, accounting for 40.06% of the global total. Among them, 19 serious disasters occurred in Asia (14 times), Africa (3 times), North America (1 time) and Europe (1 time), with more than 100 deaths each time. The deadliest event was the heatwave event in Europe, which resulted in the death of 6,340 people in total. In terms of the economic losses, North America suffered the most economic losses due to disasters, reaching USD 87.221 billion, and accounting for 50.38% of the total global economic losses. Asia came in second with USD 67.406 billion (accounting for 38.93%). Economic losses caused by disasters in Asia, North America and Europe accounted for nearly 95.14% of the total global losses. Among them, the disaster events that caused economic losses of more than USD 100 million each time occurred mostly in North America (29 times) and Asia (25 times). In addition, 17 such disaster events occurred in other parts of the world (7 in Europe; 4 in South America, 4 in Oceania and 2 in Africa).

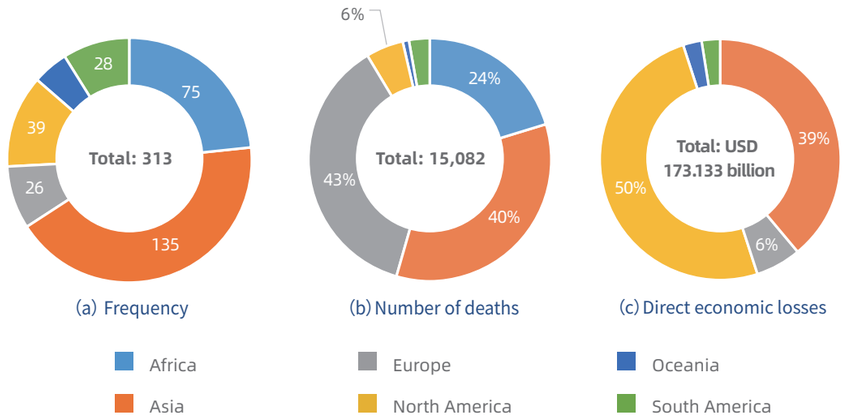


Figure10 Statistics on the frequency of natural disasters, the number of deaths and direct economic losses by continent, 2020

(Note: If a disaster event occurs across continents, it is regarded as one event on a global scale when we count up the frequency of disasters; while on a continental scale, it is counted separately according to the actual impact. In 2020, there was one earthquake and three typhoons across continents in the world.)

3.3 Natural disasters in countries or regions in 2020

Figure 11, Figure 12 and Figure 13 show the spatial distribution about the frequency of natural disasters, the number of deaths, and direct economic losses for each country or region in the year of 2020 respectively. Table 2 lists the top 10 countries in terms of the frequency of disasters, the death toll and mortality rates, direct economic losses and loss rates. The top ten countries with the highest frequency of disasters were mainly located in the southern part of North America and southern, southwestern and southeastern parts of Eurasia. Among them, Indonesia had the highest number at 29, followed by the United States at 23. China ranked third with 13 times. The countries with a larger number of disaster-related deaths were mainly located in Europe, East Asia, Southeast Asia and South Asia. The top ten countries all had more than 300 deaths, of which the United Kingdom had the largest number at 2,558, followed by India at 2,316. China ranked sixth with 464 people. Among the top ten countries with the largest number of deaths per million people, Belgium ranked first with 127.13 deaths; El Salvador ranked tenth, with 11.62 deaths. The number of deaths per million people in China was 0.33. The countries with higher direct economic losses were scattered throughout the world, distributed in Asia, Europe, North America, South America and Oceania. The top ten countries all had losses of more than USD 2 billion, of which the United States had the most, at USD 76.60 billion; India took second place with USD 26.43 billion, and China ranked third with USD 23.092 billion. In terms of the proportion of direct economic losses in GDP of the previous year, countries, except Puerto Rico, India, El Salvador and Bangladesh, were all above 1%. Tonga had the highest proportion of direct economic losses in GDP, reaching 21.66%, Bangladesh ranked tenth at 0.66%. China]s proportion of direct economic losses in GDP was 0.16%.

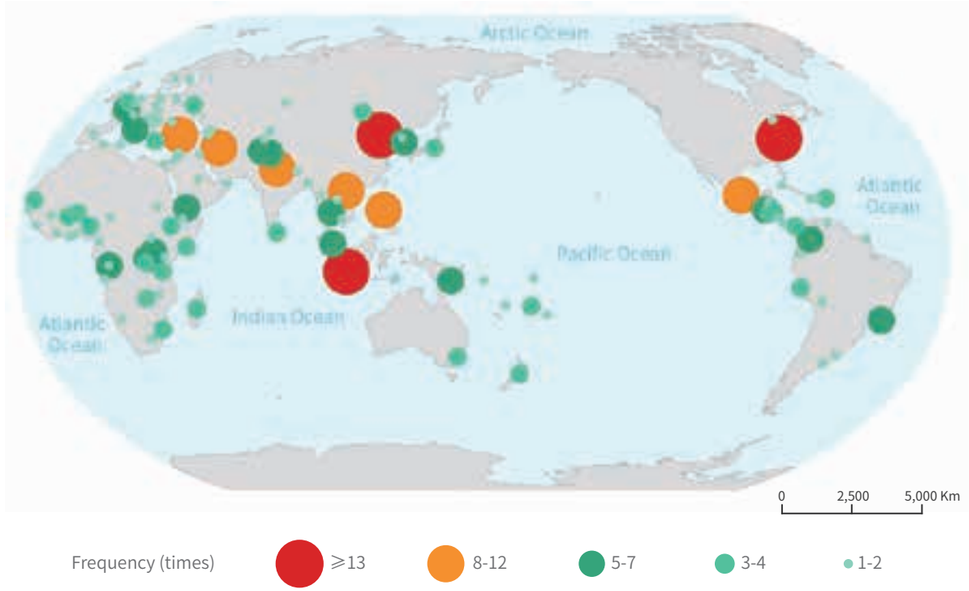


Figure 11 Spatial distribution of the frequency of natural disasters by country/region, globally in 2020

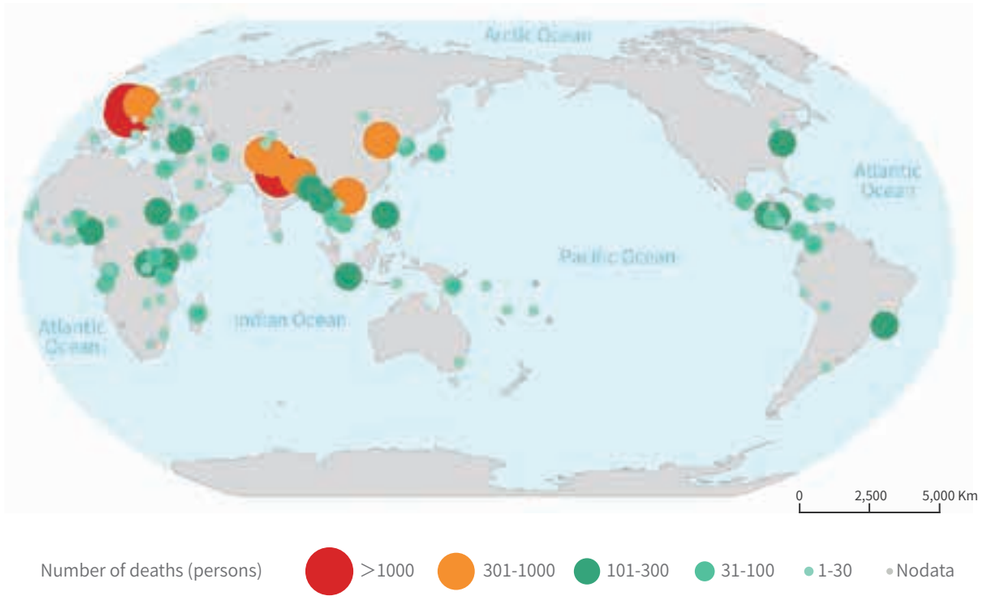


Figure 12 Spatial distribution of the death toll by natural disasters, by country/region, globally in 2020

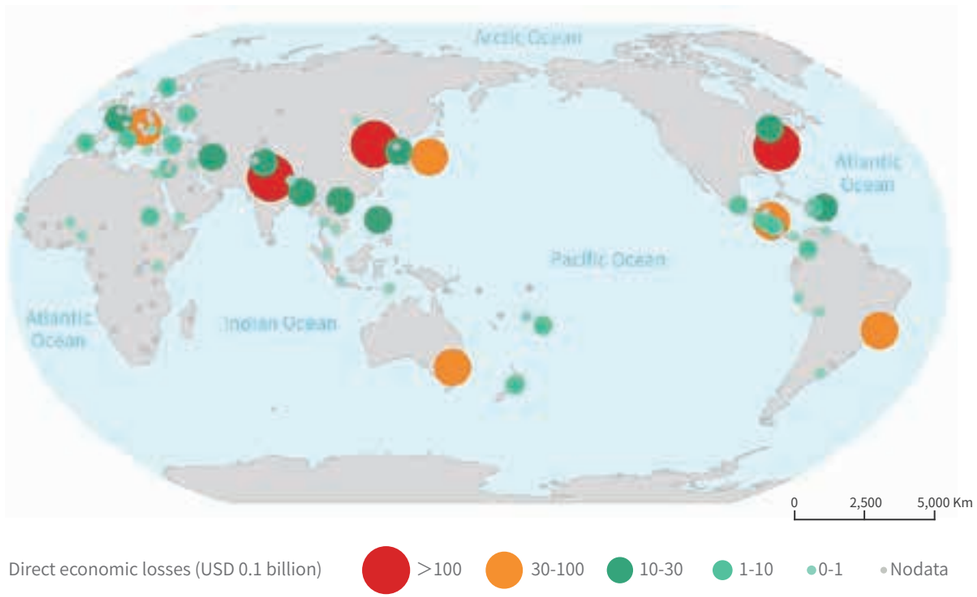


Figure 13 Spatial distribution of direct economic losses from natural disasters by country/region, globally in 2020

Table 2(a) Top 10 countries (or regions) in terms of frequency and losses caused by natural disasters globally in 2020

Country	Frequency	Country	Number of deaths	Country	Direct economic losses (USD 0.1 billion)
Indonesia	29	The United Kingdom	2558	The United States	766.00
The United States	23	India	2316	India	264.30
China	13	France	1952	China	230.92
India	11	Belgium	1460	Croatia	80.00
Vietnam	11	Pakistan	630	Japan	60.00
Turkey	10	China	464	Honduras	50.00
The Philippines	9	Nepal	448	Australia	39.00
Iran	8	The Netherlands	400	Brazil	36.00
Mexico	8	Afghanistan	328	Canada	25.00
Brazil, France, Italy, Thailand, Afghanistan	7	Vietnam	310	Iran	23.58

Table 2(b) Top 10 countries (or regions) in the world in terms of natural disaster loss rate in 2020

Country	Deaths per million population	Country	Percentage of direct economic losses (%)
Belgium	127.13	Tonga	21.66
Solomon Islands	41.80	Honduras	19.92
The United Kingdom	38.27	Croatia	13.24
France	29.11	Nicaragua	7.34
The Netherlands	23.08	Sudan	1.32
Panama	22.14	Timor-Leste	1.20
Vanuatu	16.67	Puerto Rico	0.96
Nepal	15.66	India	0.92
Honduras	13.54	El Salvador	0.81
El Salvador	11.62	Bangladesh	0.66

(Note: The number of deaths per million population in Table 2(b) refers to the proportion of the number of deaths in 2020 in the total population in 2019 (expressed as deaths per million population), and the proportion of direct economic losses in GDP refers to the total direct economic losses in 2020 as a percentage of GDP in 2019. The population and GDP (in current US dollar) data for 2019 are sourced from the World Bank (https://data.worldbank.org/)).

3.4 The top 10 global natural disasters in terms of deaths and direct economic losses in 2020

Table 3 and Figure 14 respectively show the world's top 10 disaster events with the highest death toll in 2020 and their spatial distribution. It can be seen that disasters with a larger number of deaths mainly occurred in economically backward developing countries, and most of the disasters were floods and storms. This is related to the low economic development level of these countries, weak disaster preparedness and prevention capabilities of their infrastructure, and low level of disaster monitoring and early warning, emergency rescue and medical services.

Table 3 Top 10 natural disasters in the death toll globally in 2020

Ranking	Time	Country	Disaster type	Number of deaths	Deaths per million population
1	June-August	The United Kingdom, France, Belgium, the Netherlands	Extreme temperature	6340	54.53
2	June-August 16	India	Flood	1922	1.37
3	June-September	Nepal	Flood	448	14.98
4	August 1-September	Pakistan	Flood	410	1.86
5	April 18-June 1	Kenya, Uganda	Flood	290	2.71
6	October 6-November 3	Vietnam, Cambodia, Thailand, Laos	Storm	289	1.31
7	May 21-July 30	China	Flood	280	0.20
8	June 15-September 30	Bangladesh	Flood	257	1.54
9	August 25-September 4	Afghanistan	Flood	212	5.70
10	July 1-July 2	Myanmar	Landslide	174	3.20

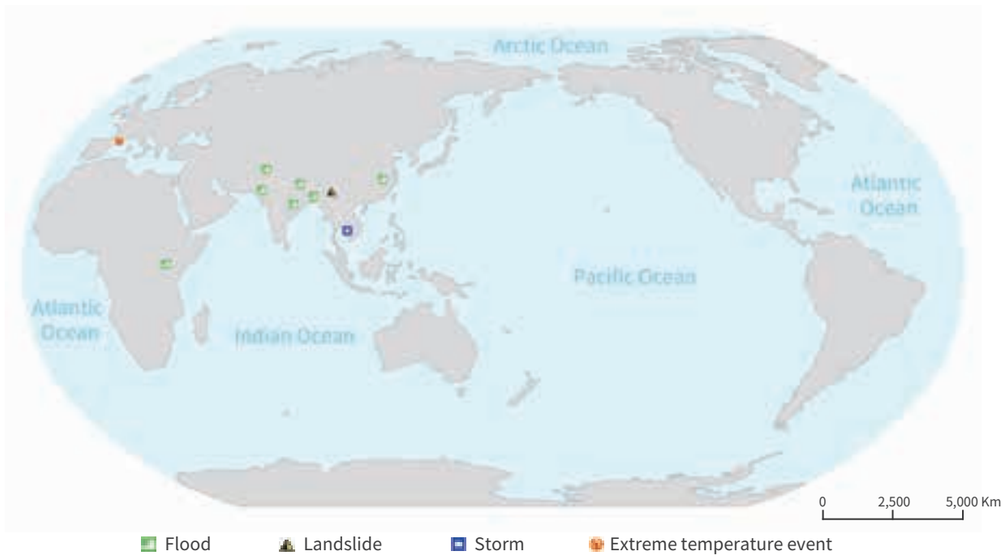


Figure 14 Spatial distribution of the world's top 10 natural disasters in deaths in 2020

Table 4 and Figure 15 list the world's top 10 disaster events with the most economic losses in 2020 and their spatial distribution. It can be seen that those events with higher economic losses mainly occurred in developing countries, and most of them were floods and storms.

Table 4 Top 10 natural disasters in direct economic losses globally in 2020

Ranking	Time	Country	Disaster type	Direct economic losses (USD 0.1 billion)
1	May 21-July 30	China	Flood	170
2	May 20-May 20	India, Bangladesh	Storm	150
3	August 27-August 28	The United States	Storm	130
4	August 16-October 1	The United States	Wildfire	110
5	June-August 16	India	Flood	75
6	November 3-November 4	Guatemala, El Salvador, the United States, Costa Rica, Mexico, Belize, Nicaragua	Storm	71
7	August 8-August 12	The United States	Storm	68
8	March 22-March 22	Croatia	Earthquake	68
9	September 11-September 18	The United States	Storm	63
10	June 29-July 10	Japan	Flood	58

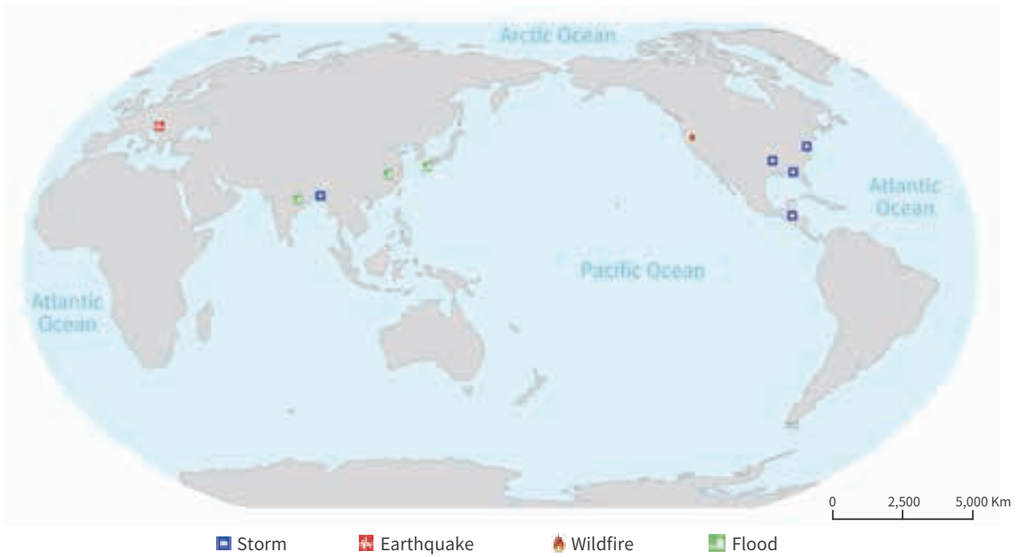


Figure 15 Spatial distribution of the world's top 10 natural disaster in direct economic losses in 2020

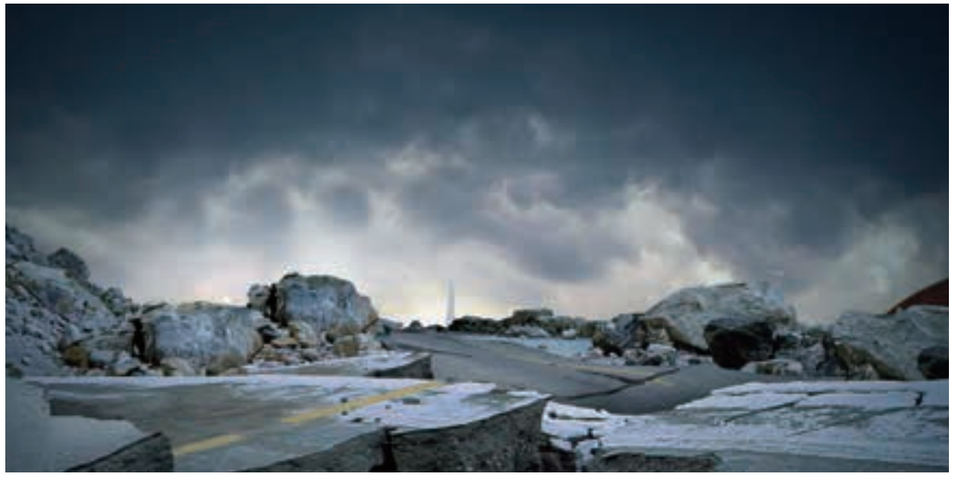
4 Comparison of natural disasters between China and the rest of the world in 2020

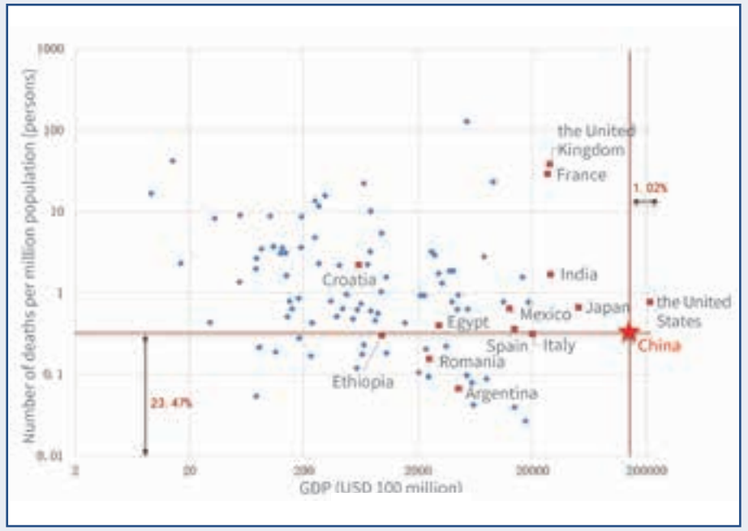
4.1 Comparison of natural disasters deaths between China and the rest of the world in 2020

Figure 16 shows the number of deaths per million population in major countries and regions around the world in 2020.

The number of disaster-related deaths per million population in China was 0.33 in 2020; among all the 98 countries and regions in the statistics, 74 countries and regions had a larger number of deaths per million people than China, accounting for 75.51% of the total; when ranked from low to high according to the number of deaths per million population, China was among the top 24.49% of the 98 countries and regions in the statistics. Countries on the same level as China included Italy (0.32 person), Spain (0.36 person) and Egypt (0.4 person), etc.

From the perspective of the relationship between the number of deaths per million people and the level of the economic development, China's number of disaster-related deaths per million people was basically consistent with the level of its economic development in 2020, and the count was relatively low in the global range. Among the countries with economic aggregates comparable to that of China, the United States (0.77 person), Japan (0.67 person) and India (1.69 persons) all had a higher number of deaths per million people than China, and the United Kingdom (38.27 persons) and France (29.11 persons) had a much higher number than China. From the perspective of countries with per capita GDP equivalent to that of China, Argentina (0.07 person) and Romania (0.15 person) had a lower number of deaths per million people than China, and Mexico (0.64 person) was higher than China.





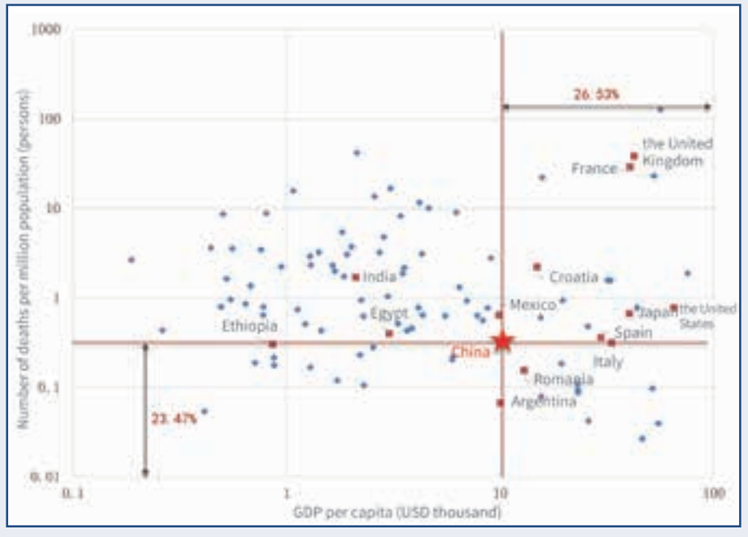


Figure 16 Comparison of natural disaster deaths between China and the rest of the world in 2020

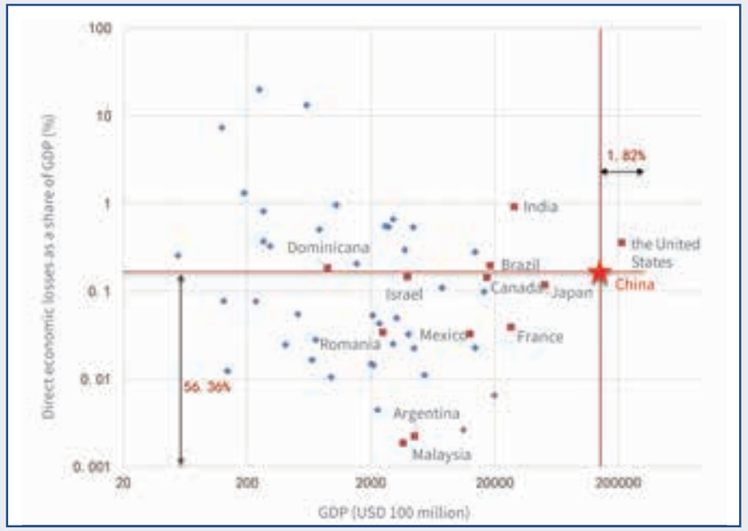
Note:
Horizontal comparison between China and the other countries and regions in the world;
China ranked in the top 24.49% in terms of the number of deaths per million population, which was in the lower-middle level;
China's total GDP ranked second; per capita GDP ranked in the top 27.55%, which was in the upper-middle level;
The number of deaths among China's millions of people basically matched its economic strength.
(The number of deaths per million population shown in the figure is calculated by dividing the number of deaths caused by disasters in 98 countries and regions around the world in 2020 by the number of million people in the previous year. The population data come from the World Bank (https://data.world-bank. org/), and GDP data are from GDP-PPP (in current US dollar) released by the World Bank in 2019)

4.2 Comparison of direct economic losses from natural disasters between China and the rest of the world in 2020

Figure 17 shows the direct economic losses as a percentage of GDP in major countries and regions worldwide in 2020.

China's direct economic losses accounted for 0.16% of its GDP; among all the 55 countries and regions in the statistics, there were 23 countries and regions with a higher economic loss ratio than China, accounting for 42% of the total; when ranked by the proportion of direct economic losses in GDP in ascending order, China was among the top 58% of the 55 countries and regions in the statistics. Countries at the same level as China included Israel (0.15%), Canada (0.14%), etc.

From the perspective of the relationship between the proportion of direct economic losses in GDP and the level of the economic development in 2020, China's direct economic losses from disasters were basically consistent with the level of its economic development, and China ranked in the upper middle position of the global range in terms of the proportion of direct economic losses in GDP. Among the countries with economic aggregates comparable to that of China, the United States (0.36%) and India (0.92%) had a higher share of direct economic losses in GDP than China, while Japan (0.12%) and France (0.04%) had a lower share than China. In terms of countries with per capita GDP equivalent to that of China, Argentina (0.002%), Malaysia (0.002%) and Mexico (0.03%) were far lower than China.



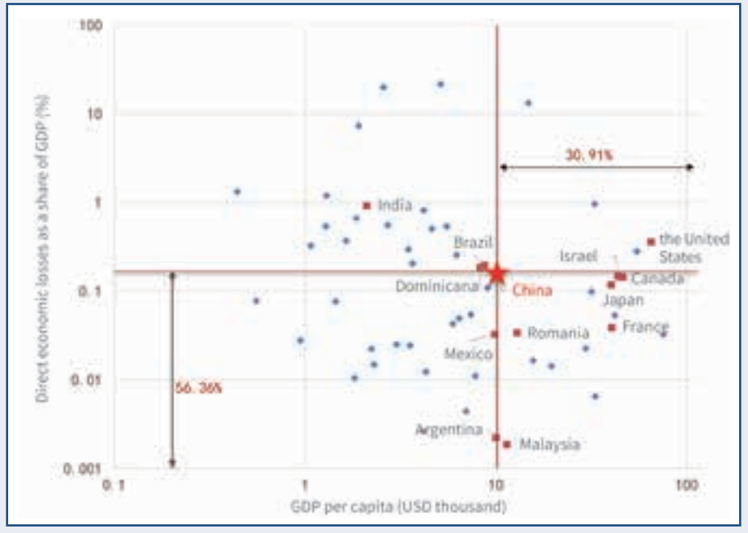


Figure 17 Comparison of direct economic losses from natural disasters as a percentage of GDP between China and the rest of the world in 2020

Note:
Horizontal comparison between China and other countries and regions in the world;
China ranked in the top 58% in terms of the direct economic losses as a percentage of GDP, which was in the middle level;
China's total GDP ranked second; per capita GDP ranked in the top 33%, which was in the upper middle level;
The proportion of direct economic losses in GDP roughly matched the economic strength.
(The direct economic losses as a percentage of GDP shown in the figure is calculated by dividing the direct economic losses from natural disasters in 55 countries and regions around the world in 2020 by the total GDP of the previous year. Population data, GDP (in current US dollars) and GDP per capita (in current US dollars) are from the World Bank (https://data.worldbank.org/)

Special Report 1

Natural disasters in China in 2020

Natural disasters in China in 2020

02

Special Report 1

Natural disasters in China in 2020

1 Overall review of natural disasters

The overall climate situation of China in 2020 was quite severe, and southern China suffered the most serious flooding season since 1998. Main natural disasters included flood, typhoon, and drought, while strong wind and hail, earthquake, cold wave, landslide and forest and grassland fires also occurred to varying degrees. Reviewed disaster losses in 31 provinces (autonomous regions, municipalities) and the Xinjiang Production and Construction Corps throughout this year read an affected population of 138 million people, death and missing toll of 591 people (522 people died and 69 people were missing), an evacuated population of 5.891 million people; collapsed housing of 100,000 rooms, severely damaged housing of 303,000 rooms, moderately damaged housing of 1.457 million rooms; affected crops of 19,957.7 thousand hectares, including destroyed crops of 2,706.1 thousand hectares; and the direct economic losses of 370.15 billion CNY.

138 million
Affected population

5.891 million
Urgently transferred and resettled population

19957.7 thousand hectares
Area of affected crops

370.15 billion CNY
Direct economic losses

1.1 Affected population by disasters

Among all disasters, flood accounted for the highest proportion (56.8%) of affected population, followed by drought (17.5%), strong wind and hail (10.9%), typhoon (7.7%), and cold wave (6.9%). Earthquake, landslide and other disasters accounted for a relatively low proportion.

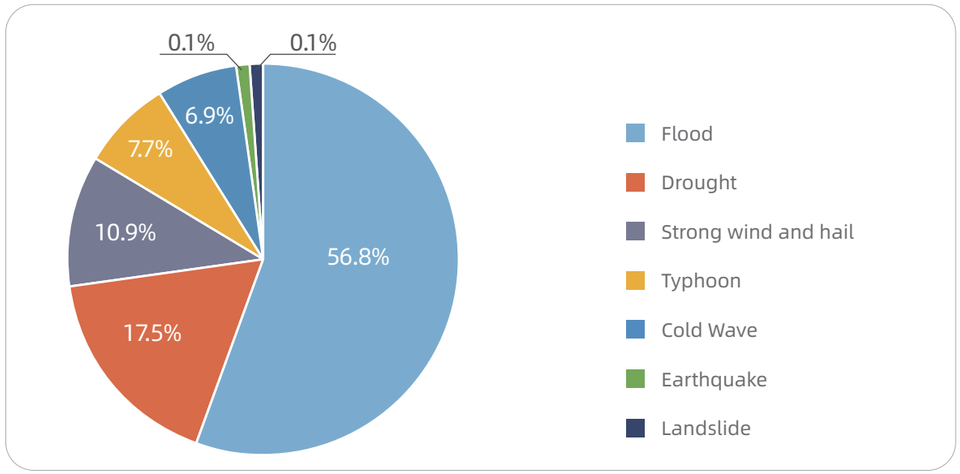


Figure 1 Pie chart of affected population by disasters in 2020

1.2 Death and missing toll by disasters

In 2020, flood accounted for the highest proportion (47.2%) of death and missing toll, and landslide (28.9%), strong wind and hail (15.7%) and forest and grassland fires (5.7%) followed. Proportions of typhoon, earthquake, cold wave and other disasters were relatively low.

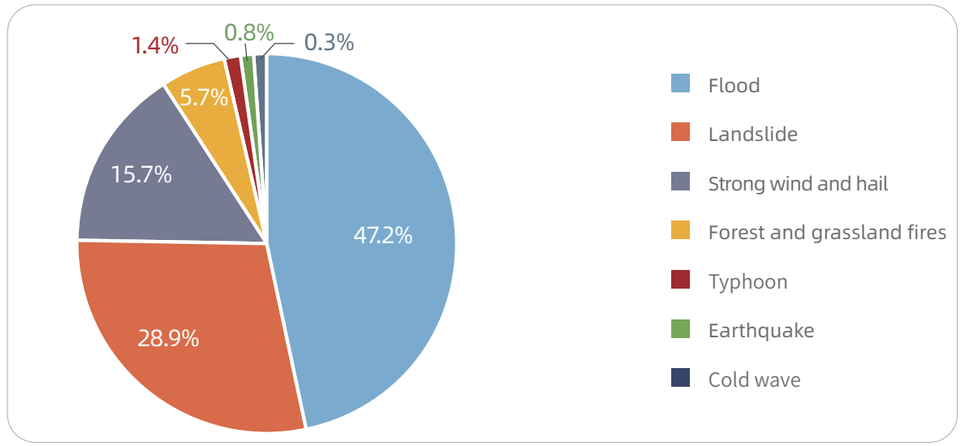


Figure 2 Pie chart of death and missing toll by disasters in 2020

1.3 Direct economic losses by disaster types

Flood caused the most direct economic losses, which accounted for as high as 72.1% of the total statistics. Typhoon (8.4%), hail (7.6%), drought (6.7%), and cold wave (4.2%) followed. Earthquake, landslide and other disasters accounted for a relatively low proportion.

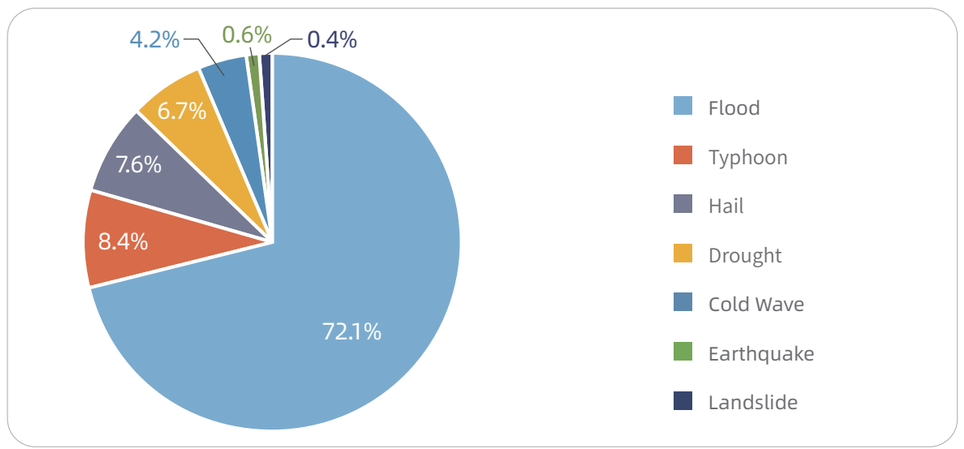


Figure 3 Pie chart of direct economic losses caused by disasters in 2020

1.4 Death and missing toll by province

Sichuan, Yunnan, Guizhou, Hubei, Chongqing, Guangxi, Gansu and Shaanxi had more than 30 deaths and missing people due to disasters in 2020, ranking the top 8. Sichuan is the only province which suffered a death and missing toll of more than 100 people. Compared with annual means from 2010 to 2019, except Heilongjiang and Xinjiang Production and Construction Corps, all provinces had decreases on these statistics.

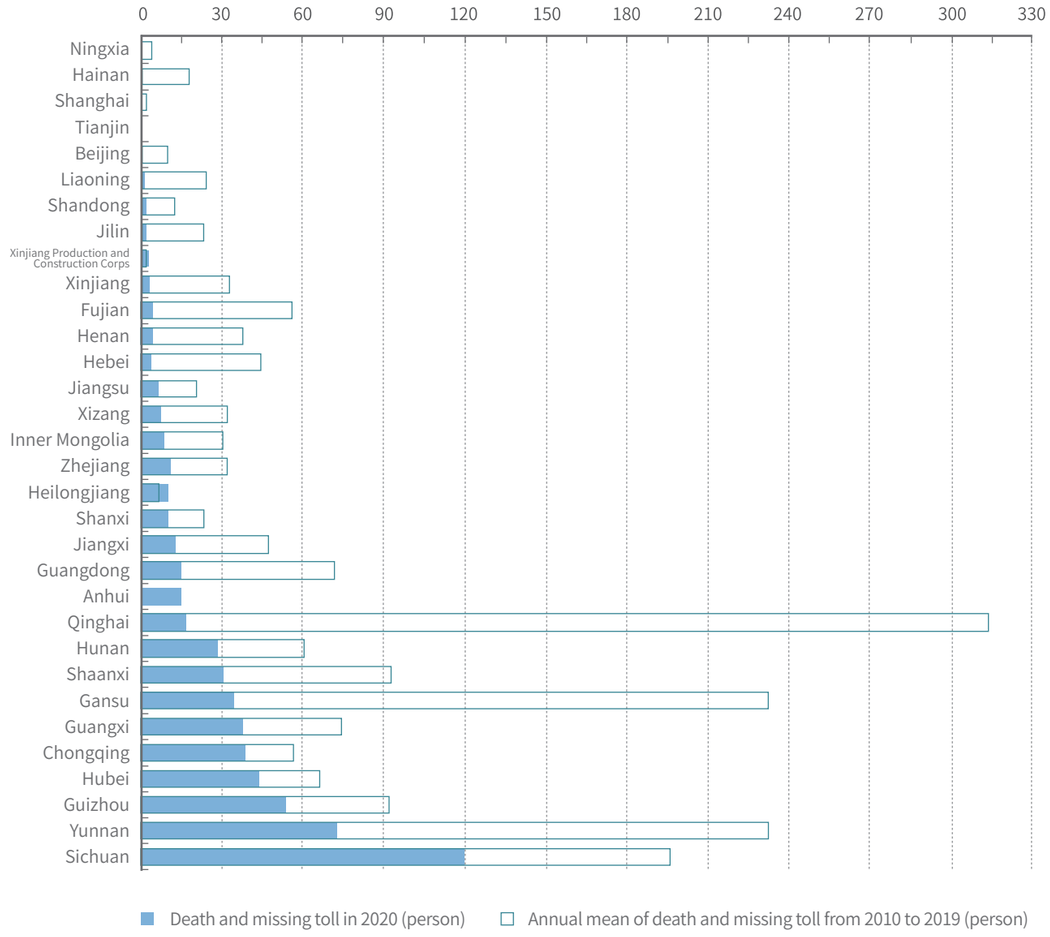


Figure 4 Statistics of death and missing toll by province in 2020

1.5 Direct economic losses by province

Thirteen provinces (autonomous regions and municipalities), including Anhui, Sichuan, Jiangxi, Hubei, Gansu, Chongqing, Hunan, Heilongjiang, Zhejiang, Yunnan, Guangxi, Inner Mongolia, and Shandong, all suffered direct economic losses of over 10 billion CNY in 2020, which ranked top places in China. Compared with annual means from 2010 to 2019 (annual data were converted to baseline 2020 according to gross regional products (GRP) indices), direct economic losses in Anhui, Chongqing and Jiangxi had positive growth while loss statistics in other provinces decreased.

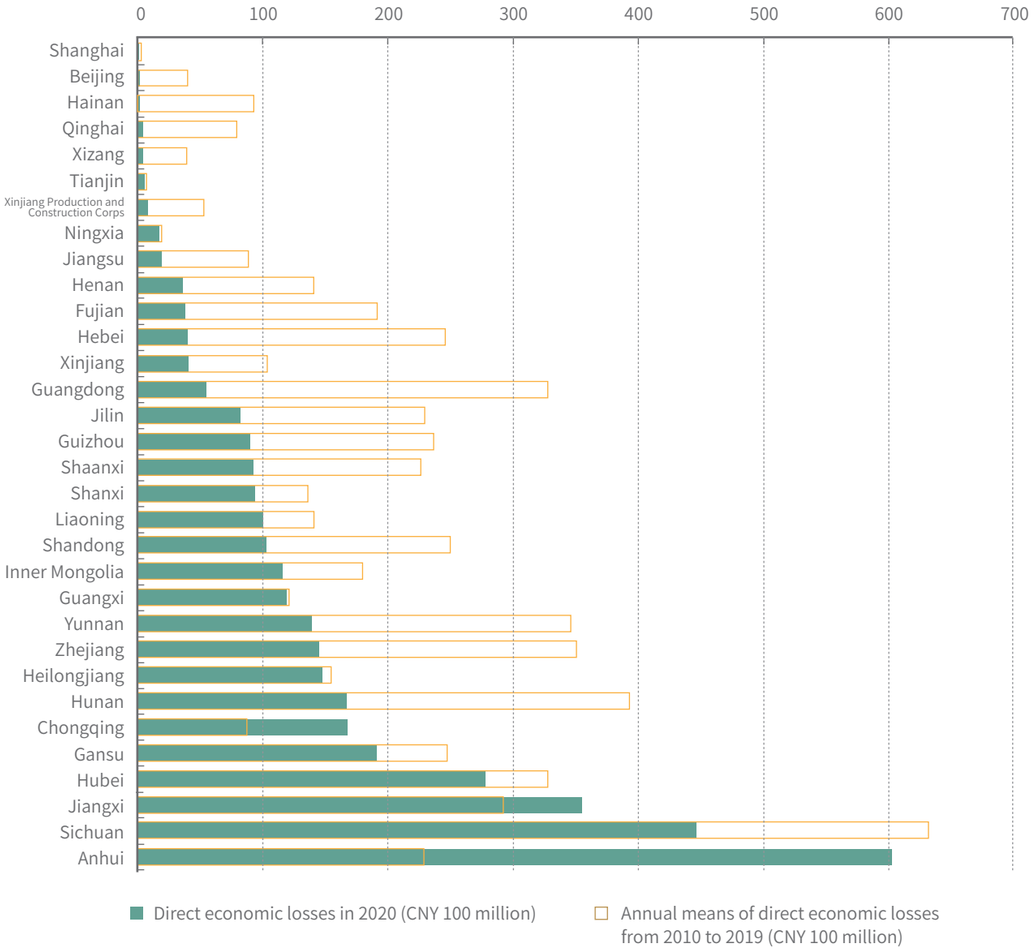


Figure 5 Statistics of direct economic losses from disasters by province in 2020

(Annual data in each province were converted to baseline 2020 according to gross regional products (GRP) indices)

Table 1 Top ten natural disaster events in China, 2020

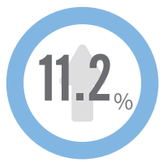
Natural disaster event	Affected population (10,000 people)	Death and missing toll (person)	Direct economic losses (100 million CNY)
(1) Extraordinarily heavy rain and floods in the Yangtze and Huaihe River basins in July	3417.3	107	1322
(2) Severe rainstorms and heavy floods in Sichuan, Chongqing, Shaanxi, Gansu and Yunnan in mid-August	852.3	71	609.3
(3) Heavy rain and floods in south of the Yangtze river and south China in early and mid-June	714.4	63	210.6
(4) Heavy rain and floods in southwest China in late June	597.8	39	113.7
(5) Typhoon Hagupit (2004)	188	5	104.8
(6) Qiaojia earthquake of Ms. 5.0 in Yunnan	1.1	4	1.01
(7) Jiashi earthquake of Ms. 6.4 in Xinjiang	11.5	1	16.2
(8) Three successive typhoons to northeast China in one month	804.5	0	172.9
(9) Cold wave to north and northwest China in late April	432.3	0	82
(10) Spring-Summer drought in Yunnan	589	0	34.9
Total losses of top 10 natural disaster events	7608.2	290	2667.41
National total losses	13829.8	591	3701.5
Percentage of top 10 natural disaster events	55.0%	49.1%	72.1%

2 Temporal and spatial characteristics of disasters

2.1 Southern China suffered the most severe flooding season since 1998, with wide range of impact but significant decrease of fatalities to historical average

There were 33 large-scale heavy rainfalls across the country in 2020, with an average precipitation of 689.2 mm, which was 11.2% more than annual normal and the third highest since 1961. Rainfall during the flooding season mainly concentrated in the middle and lower reaches of the Yangtze River. There were 10 consecutive heavy rainfall processes in this region. The rainy season lasted for 62 days with highly overlapped areas, and the rainfall was the highest since 1961. Major rivers such as the Yangtze River, the Yellow River and the Huaihe River experienced 21 numbered floods, more than statistics in 1998. A basin flood occurred in the Yangtze River and a catastrophic flood occurred in the upper reaches. As a result, the inflow of the Three Gorges Reservoir reached 75,000 cubic meters per second, which was the largest flow since its completion. Taihu Lake experienced a basin flood with the third highest water level in history. Large basin floods occurred in both the Huaihe River and the Songhuajiang River. Under such severe climate conditions, flood disasters in this year demonstrated a characteristic of "three increases and two decreases". Statistics of affected population, evacuated population and direct economic loss increased by 23%, 62% and 59%, respectively, compared with annual mean of the past five years. Death and missing toll and collapsed housing, however, decreased by 53% and 47% respectively. In addition, due to high frequency, high intensity and wide range of heavy rainfall, subsequent geological disasters occurred more than previous years, which were mainly of small and medium scale. Landslides in southwest China were more severe, which accounted for more than half of the total losses.

large-scale heavy rainfalls



more than annual normal

2.2 A wide range of territory was affected by strong wind and hail disasters, with significant difference between the north and the south

A total of 58 large-scale short-term strong convective weather processes, including heavy rain, thunderstorm, gale, and hail, occurred across the country in 2020. This count was significantly higher than the average level of the past five years. Total 1,367 county-level administrative regions across the country were affected by wind-hail disasters, causing 15.14 million people affected and 93 people dead or missing. Disaster impacts varied greatly from north to south. The main differences were as follows. In the north, strong convective disasters characterized by strong wind and hail caused main impacts, which occurred in May and June and resulted in heavy losses to crops. While in the south, continuous and concentrated short-term heavy rainfall and thunderstorms caused main impacts. From July to August, event counts of thunderstorms and gales in the Sichuan Basin and the Yangtze River Basin were the highest since 2011. Besides, lightning strikes that caused fatalities occurred frequently.

large-scale short-term strong convective weather processes

2.3 Varying temporal-spatial patterns for typhoons, with certain impact to east and northeast China

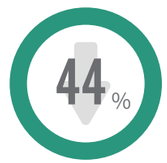
Total of 23 tropical cyclones were generated in northwest Pacific and the South China Sea in 2020, 3.8 fewer than the annual average. Among them, 5 typhoons made landfalls in China, 2 less than annual mean level. Specifically, no typhoon was generated in the South China Sea and west Pacific in July, which was extremely rare and made this July the first "no typhoon month" since 1949. In early and mid-August, Typhoons Hagupit (2004), Mikra (2006) and Hygauss (2007) intensified rapidly in offshore areas and all made landfalls in coastal areas of east and south China at their peak intensities, which caused great impact to east China. Among them, Typhoon Hagupit had severe impact to Zhejiang Province. From late August to early September, within two weeks, Typhoon Bahwe (2008), Mesaq (2009) and Poseidon (2010) went northward and affected northeast China consecutively, with high overlap of affected areas. Continuous rainfall brought by these three typhoons caused the water levels of the Nenjiang, Songhuajiang, Heilongjiang and other major rivers exceeding the warning line, and large areas of crops in Heilongjiang Province and Jilin Province got flattened.

typhoons made landfalls in China

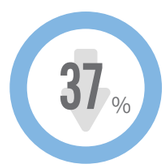
less than annual mean level

2.4 Obvious periodic and regional characteristics of drought

Disaster impact of drought in 2020 was significantly lighter than previous years. The main climate events included the winter-spring drought in southwest China, spring drought in north China, summer drought in northeast China, and local drought in southern China at the end of the year. During the flooding season, precipitation in most areas was more than that in the normal years, and farming lands were in good condition. In some areas, drought and flood disasters quickly reversed, or coexisted. 4 provincial administrative regions, namely, Sichuan, Chongqing, Liaoning, and Jilin, had severe droughts in early summer. However, after entering the flooding season, high-intensity rainfall continued to appear, and droughts and floods in 6 cities (prefectures) and 64 counties (districts) quickly reversed. During this season, rainfall was unevenly distributed in Jiangxi Province and Hunan Province. There were floods in the north and droughts in the south, and droughts and floods coexisted. Overall speaking, area of affected crops and direct economic losses by drought in 2020 decreased by 44% and 37%, respectively, compared with the average of the past five years. Yunnan, Liaoning, Shanxi, Sichuan, Inner Mongolia, and Shaanxi had relatively severe impacts.



Compared with the average of the past five years, area of affected crops decreased by



Compared with the average of the past five years, direct economic losses decreased by

2.5 Forest and grassland fires showed a downward trend of disaster impact, with relatively concentrated distribution in time and space

There were 1,153 forest fires nationwide (including 7 major forest fires but no catastrophic forest fires) in 2020, and area of affected forests was 8,526 hectares. 13 grassland fires occurred, and affected area was 11,046 hectares. Compared with the average statistics in recent years, the number of forest and grassland fires, affected area, and casualties all decreased significantly. In terms of time distribution, forest fires were mainly concentrated from February to May. During this period, frequent human activities in the forest, such as spring plowing, burning paper on graves, and outings in the wild, led to an increase in fire incidents. Total 780 cases occurred, which accounted for 70% of the annual total counts. In July, lightning fires broke out in a concentrated pattern, and 130 forest fires were caused by lightning strikes throughout the year, which increased 8.3% more than 2019. From a regional perspective, fire risks in southwest China were superimposed by drought. Guangxi, Sichuan and Shaanxi had more forest fires, which accounted for more than 30% of the total event counts.

2.6 Earthquake intensity was generally weak, with many moderate-strong earthquakes in the west

There were 20 earthquakes of Ms. 5.0 or higher in the Chinese mainland (including 17 earthquakes of Ms. 5.0-5.9 and 3 earthquakes of magnitude Ms. 6.0-6.9) in 2020, which was lower than the annual average since 1950. In the first half of the year, earthquake impact was severe. The number of earthquakes of Ms. 5.0 or above accounted for 80% of the whole year's count. Among them, the Jiashi Ms. 6.4 earthquake in Xinjiang on January 19 and its aftershocks caused 1 death and more than 800 houses collapsed. On May 18, Yunnan Qiaojia Ms. 5.0 earthquake killed 4 people and damaged more than 1,100 houses to varying degrees. Throughout this year, earthquakes of Ms. 5.0 and above in the Chinese mainland mainly occurred in Xinjiang, Xizang, Sichuan and Yunnan. The Ms. 6.6 earthquake in Nima County, Tibet on July 23 had the highest magnitude in 2020. However, the epicenter was located in a sparsely populated area at high altitude, and only about 50 old houses were damaged with no casualties.

2.7 Cold wave had impact to local areas

There were 18 cold waves across the country in 2020, close to normal level. In April, two cold waves caused large-scale temperature drop and snowfall in northwest China, north China and Shandong Province. The minimum temperature in Shandong, Hebei, Shanxi and some other places dropped below zero, causing a large area of vegetables and fruits frozen. In November and December, there were two large-scale cold waves, characterized by frozen rain, snow, and low-temperature, in the central and eastern regions, causing 7 provinces affected to varying degrees. The temperature drop in some areas reached 12~14°C, and power facilities in some places were damaged due to rare low-temperature. In December, southern regions such as Hunan, Fujian and Guangxi suffered low-temperature freezing disasters, and crops suffered certain losses.

3 Trend analysis of disaster indicators

3.1 Affected population

Overall speaking, affected population by various natural disasters across the country has demonstrated a downward trend since 2000. Affected population in 2020 was 138.298 million person-times, ranking the third lowest since 2000 (only higher than 2018 and 2019). Compared with the annual average from 2000 to 2019 (331.57 million person-times, 2008 excluded), these statistics have dropped by 58.3%.

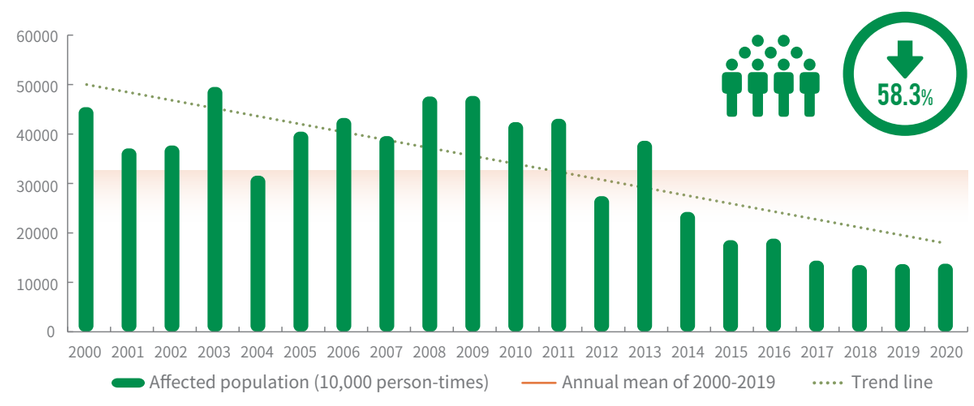


Figure 6 Annual statistic of affected population in China since 2000

3.2 Affected people per 100,000 population

The statistics of affected people per 100,000 population have also shown a decreasing trend since 2000. In 2020, the number of affected people per 100,000 population was 9,845, which was the third lowest since 2000 and dropped by 60.7%, compared with the annual mean from 2000 to 2019 (25,026 people, 2008 excluded).

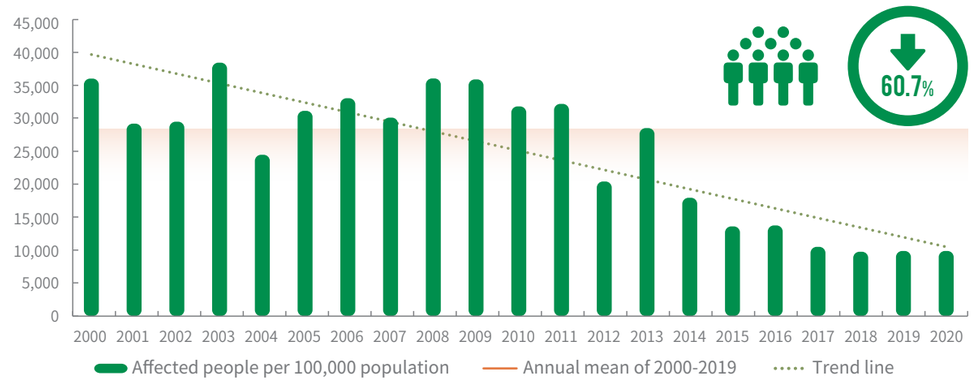


Figure 7 Annual statistics of affected people per 100,000 population in China since 2000.

3.3 Death and missing toll

From 2000 to 2020, annual death and missing toll caused by various natural disasters across the country was also declining. The toll in 2020 was 591, ranking the lowest since 2000. Compared with the average level in 2000-2019 (2,216 people, 2008 excluded), the decrease was as high as 73.3%.

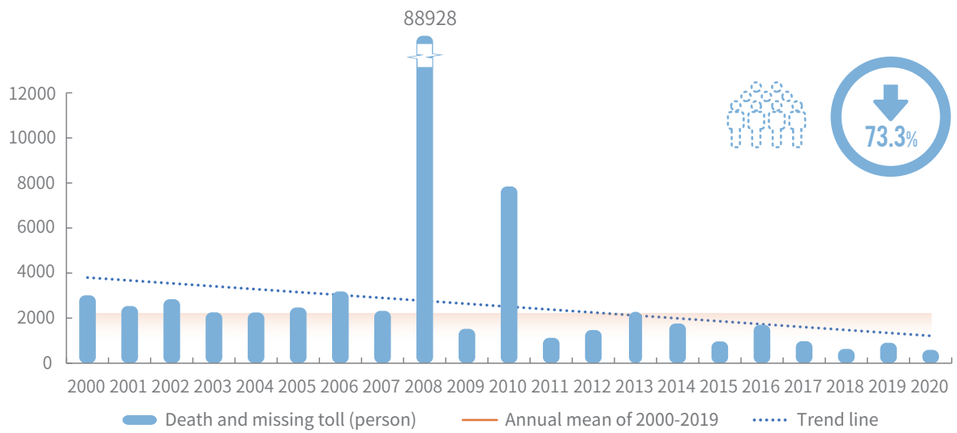


Figure 8 Annual statistics of death and missing toll in China since 2000

3.4 Death and missing toll per 100,000 population

As to death and missing toll per 100,000 population, this rate went down as well, which reached the lowest level, that was, 0.037, in 2020. The decrease was 78.2% to the annual mean from 2000 to 2019 (0.17, 2008 excluded).

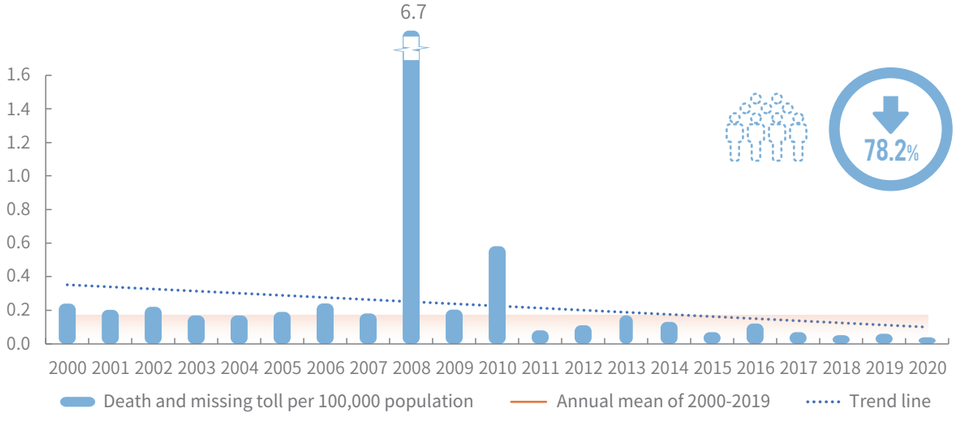


Figure 9 Annual statistics of death and missing toll per 100,000 population in China since 2000

3.5 Direct economic loss

From 2000 to 2020, direct economic losses caused by various natural disasters across the country have showed a downward trend (annual data were converted to baseline 2020 according to the GDP index). The loss data in 2020 read 370.15 billion CNY, ranking the fourth lowest since 2000 (only higher than 2017, 2018 and 2019), with a decrease of 44.2% to the annual mean from 2000 to 2019 (663.5 billion CNY, 2008 excluded).

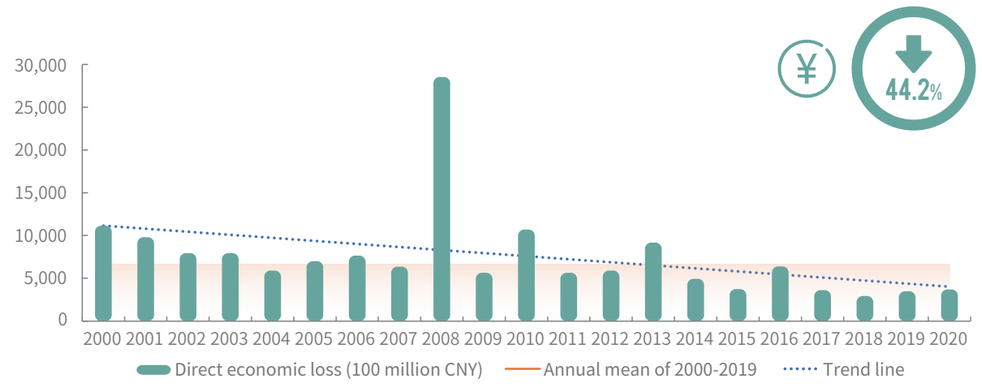


Figure 10: Annual statistics of direct economic losses in China since 2000.
(Annual data were converted to baseline 2020 according to the GDP index)

3.6 Direct economic losses over GDP

The ratio of direct economic losses caused by various natural disasters across the country over GDP was also declining. In 2020, this ratio was 0.36%, which was the fourth lowest since 2000 (only higher than 2017, 2018 and 2019) and decreased by 60.9% to the average level from 2000 to 2019 (0.92%, 2008 excluded).

Figure 11 Annual statistics of direct economic losses over GDP in China since 2000

Special Report 2

Cumulative losses should be emphasized in flood risk management

Cumulative losses should be emphasized in flood risk management

03

Special Report 2

Cumulative losses should be emphasized in flood risk management

1 Research background and objectives[2]

Flooding has caused heavy casualties to China and even the world, and many people were affected by that. A large number of estimates and studies have pointed out that flood disasters will occur more frequently in the context of future global changes. Therefore, effective flood risk management is imperative, and effective flood risk management decisions depend to a certain extent on the level of knowledge of flood risk.

The total loss due to floods within a certain period of time in a region is determined by the single loss and its frequency. At present, due to the wide range of impacts and huge losses, severe and rare flood disaster events are attracting more attention, while other types of floods, especially small flood events, have received insufficient attention. Although small and frequent flood disaster events have relatively small impact range and loss, their high frequency may also cause cumulative losses comparable to severe and rare flood events. Therefore, focusing only on severe and rare flood events cannot provide complete information about the long-term flood impacts to the region, but by analyzing the cumulative effects of various types of floods (severe and rare, moderate, small and frequent) in the region, more detailed information can be provided. Flood risk information research based on historical loss data mostly focuses on typical historical severe and rare flood events. Only a few regional studies have shown that small-scale but high-frequency flood events within a certain period of time can cause almost the same cumulative loss as severe and rare flood disasters. In addition, flood risk analysis based on climate change projections mostly focuses on extreme flood events, and less attention is paid to the future impact of small and frequent flood events on population, economy, etc. However, historical records and climate change projections indicate that small and frequent flood events may occur more frequently in the future, and their cumulative impact deserves attention.

At present, the research on the relative importance of the cumulative effects of different types of floods in a certain period of time is still insufficient. Therefore, this report and a few related studies which are based on historical records or risk assessment complement each other. Taking the indicators of flood deaths and affected people as examples, based on the global flood deaths and affected population recorded in the EM-DAT database from 1976 to 2020, this report analyzes the relative importance of the cumulative loss of severe and rare floods and small and frequent floods, and gains insight into the demographic impact structure of floods in China and the world, in order to provide a reference for flood risk prevention in the context of climate change.

2. Due to space limitations, for more details please refer to the references in the paper Chen, B., F. Shi, T. Lin, P. Shi, and J. Zheng, 2020. Intensive Versus Extensive Events? Insights from Cumulative Flood-Induced Mortality Over the Globe, 1976–2016. International Journal of Disaster Risk Science 11(4): 441-451

2 Data and methods

2.1 Data

The study uses the EM-DAT database developed and maintained by the Centre for Research on the Epidemiology of Disasters (CRED) in Belgium. It contains data on flood loss in countries around the world since 1900, including the number of deaths, the number of people affected, the area affected, economic losses, flood types, and date of occurrence, etc. In order to reduce the impact of incomplete records on the analysis results, this study selected the number of flood deaths and affected people in the past 45 years (1976-2020) as indicators. During this period, the database recorded 4,751 flood events. Among them, 83% of the incidents (3,932) affected more than 100 people each time; in these 3,932 incidents, about 43% of the incidents had fewer than 3 deaths. The data show that from the perspective of the number of deaths and affected people and the relative significance, the EM-DAT database contains flood disaster events with different loss intensities.

2.2 Method

2.2.1 Classification of flood events based on the size of the loss

Taking the indicator of the number of flood deaths (people affected) recorded in the international disaster database EM-DAT in the past 45 years (1976-2020) as an example, the frequency analysis of the loss data is carried out first. Flood events in which the number of deaths (people affected) exceeds that of a catastrophic flood that occurs only once every twenty years are defined as "severe and rare", flood events in which the number of deaths (people affected) is less than that of a flood that occurs every two years are defined as "small and frequent", and flood events which will be between the two types of flood events (20 annual and biannual) are defined as moderate flood events. Based on this, it further proposes and analyzes the cumulative loss ratio of large and small disasters and the statistical distributions of loss, and compares the relative importance of cumulative loss of severe and rare floods and small and frequent floods in China and other countries (top 30).

First, select a sequence of deaths (people affected by disasters) exceeding the threshold level in T years within a region (global or national), and sort from big to small as $\{D_1, D_2, D_3, \ldots, D_m, \ldots, D_T\}$, then the exceedance probability of the number of deaths (people affected) D_m can be expressed by Weibull's formula (1) as:

$$P(D \geqslant D_m) = \frac{m}{T+1} \tag{1}$$

From this, the exceedance probability can be determined: the number of deaths (people affected) corresponding to the floods that occur once every two years and the floods that occur only once every 20 years, that is, the threshold for dividing small and frequent flood events and severe and rare flood events.

2.2.2 Cumulative loss ratio of large and small disasters

This study defines the cumulative loss ratio (CLR) of large and small disasters as the ratio of the cumulative loss caused by small and frequent floods to the cumulative loss caused by severe and rare floods over a period of time:

$$CLR = \frac{CL_{extensive}}{CL_{intensive}} \tag{2}$$

Among them, $CL_{extensive}$ and $CL_{intensive}$ are the cumulative losses caused by small and frequent floods and severe and rare floods in the same period, respectively. The definitions are as follows:

$$CL_{extensive} = N\int_{0}^{L_{2\text{-}yr}} L \times P(L) \times dL \tag{3}$$

$$CL_{intensive} = N\int_{L_{20\text{-}yr}}^{\infty} L \times P(L) \times dL \tag{4}$$

Where N is the frequency of flood events, L is the loss of a single event, P(L) is the probability density function of the loss, $L_{2\text{-}yr}$ and $L_{20\text{-}yr}$ are the losses corresponding to the 2-year and 20-year return periods respectively.

The value of the cumulative loss ratio (CLR) of large and small disasters is non-negative, and a value of 1 indicates that the cumulative loss caused by small and frequent floods is equal to the cumulative loss caused by severe and rare floods. The greater the cumulative loss ratio (CLR) of large and small disasters, indicates that, relatively speaking, the cumulative losses caused by small and frequent floods are more important. If the situation is opposite, it indicates that the cumulative losses caused by severe and rare floods are more important.

3 Results

3.1 Deaths from floods

In the past 45 years, small and frequent flood events have had a major impact on the number of people who died from floods in the world. During the period, among the top 30 countries in terms of the number of global flood deaths, the cumulative death toll of small and frequent floods in about half of the countries exceeded that of severe and rare floods. In the past 15 years, flood control in China and around the world has effectively reduced the number of flood deaths. Since small and frequent floods accounted for more than 75% of the total deaths, we should continue to pay more attention.

3.1.1 The cumulative number of deaths caused by small and frequent floods in China in the past 45 years has exceeded that of severe and rare floods

EM-DAT statistics show that in the past 45 years (1976-2020), floods have caused a relatively high number of deaths in China, and the cumulative deaths caused by small and frequent floods have exceeded those caused by severe and rare floods. During this period, there were a total of 308 floods in China. Except for 37 floods that did not cause deaths, the remaining floods caused 44,327 deaths in total. Among them, the thresholds for small and frequent (once in 2 years) and severe and rare (once in 20 years) events are 365 and 3,315 deaths in a single event, respectively.

From 1976 to 2020, there were a total of 249 small and frequent, 20 medium and 2 severe and rare flood events in China. Two severe and rare floods (the red columns in Figure 1) occurred in 1980 and 1998, causing 6,200 and 3,656 deaths respectively; however, 249 small and frequent floods (the orange columns in Figure 1) cumulatively caused 14,307 deaths, which is 1.45 times the total number of deaths caused by the two severe and rare floods (Figure 1, the cumulative loss ratio of large and small disasters is 1.45). It is worth noting that the black columns in Figure 1 represent moderate flood events, which caused about 45% of the total flood deaths in China.

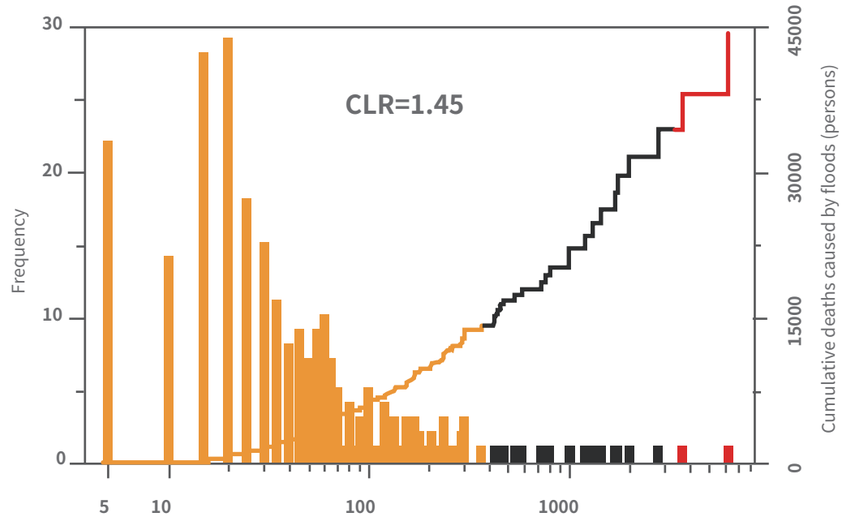


Figure 1 Statistical distribution of flood deaths in China from 1976 to 2020

3.1.2 In the past 45 years, among the top 30 countries with the highest number of deaths due to floods, the cumulative number of deaths caused by small and frequent floods in about 50% of these countries has approached or exceeded that caused by severe and rare floods

EM-DAT global statistics show that flood events have caused a relatively high number of deaths in the past 45 years (1976-2020), and the cumulative deaths caused by small and frequent floods have exceeded those caused by severe and rare floods. During this period, a total of 4,751 floods occurred globally. Except for about 30% of the floods that did not cause deaths, the remaining floods caused a total of more than 250,000 (255,230) deaths. Among them, the thresholds for frequent small-scale floods and rare high-intensity flood events are 1,350 and 6,145 deaths in a single event, respectively. Two severe and rare flood events occurred in Venezuela and China in 1999 and 1980, causing the deaths of 30,000 and 6,200 respectively (the red columns in Figure 2). Globally, the cumulative number of deaths caused by frequent small-scale floods (orange columns in Figure 2) is 4.83 times the total number of deaths caused by two rare high-intensity floods (Figure 2, the cumulative loss ratio of large and small disasters is 4.83). The black columns in Figure 2 represent moderate flood events (the deaths caused by a single event is between those caused by floods that occur once in 2 years and once in 20 years), which caused approximately 17% of the world's total deaths from floods between 1976 and 2020.

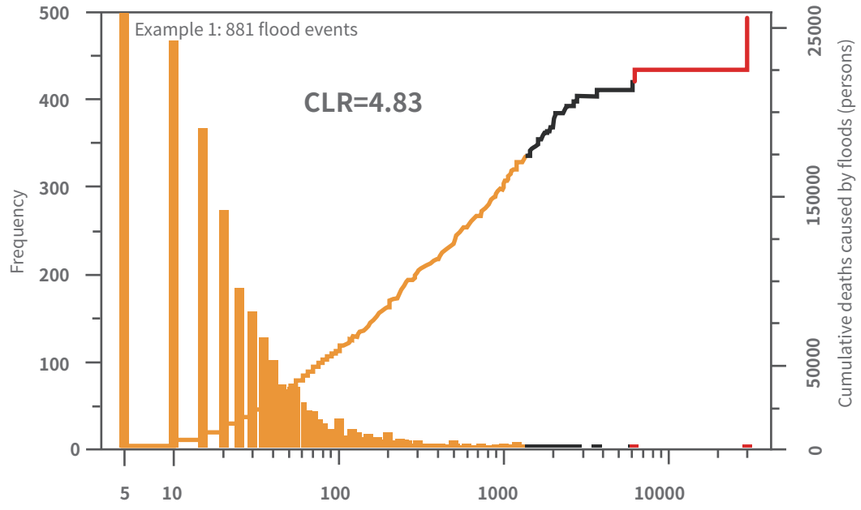


Figure 2 Statistic distribution of global flood deaths from 1976 to 2020

Among the top 30 countries with the largest flood deaths in the world, about 50% of countries have had small and frequent floods whose cumulative deaths have been close to or exceed those of severe and rare floods (cumulative loss ratio CLR ⩾ 1, Figure 3). When it comes to deaths caused by floods, small and frequent floods are always an important category for most countries. In addition, the cumulative loss ratio of large and small disasters in terms of deaths caused by floods in these countries is not highly correlated with the total number of deaths caused by floods. One is that the correlation between the two did not pass the significance test at the p=0.10 level, and the second is that it can be seen from Figure 3 that the cumulative loss ratio of large and small disasters in countries with high total flood deaths may be larger (such as China) or smaller (such as Bangladesh). Countries with low total flood deaths may have a larger cumulative loss ratio (such as the United States) or a smaller cumulative loss ratio (such as Colombia).

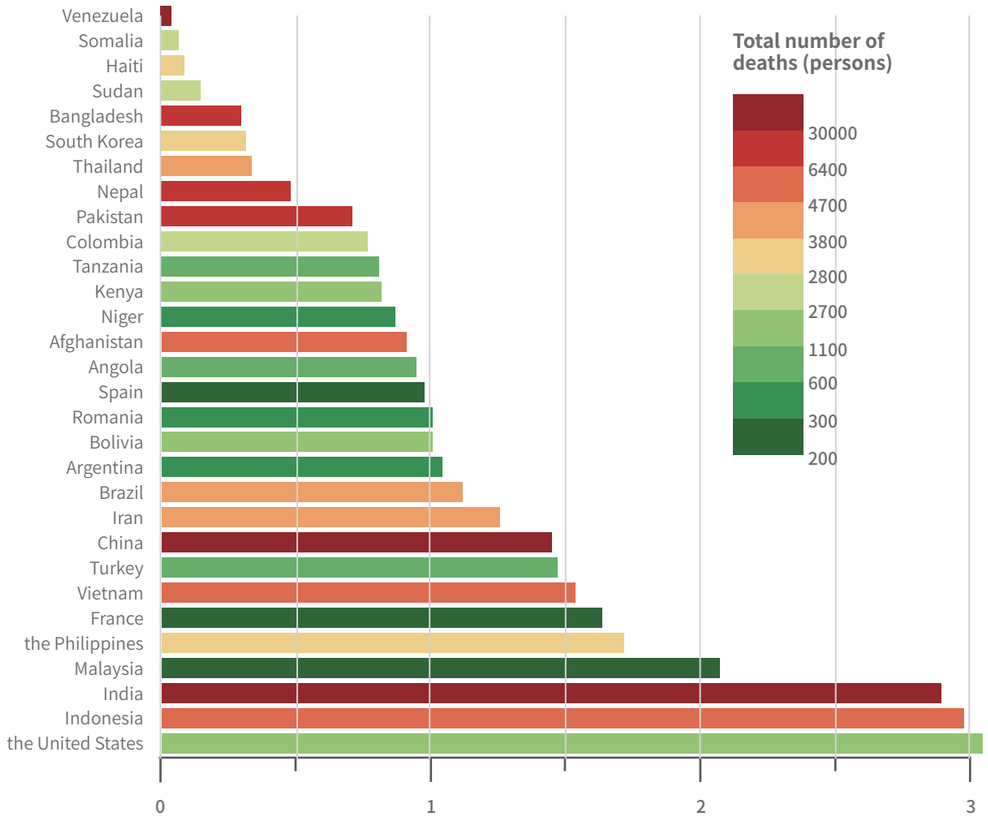
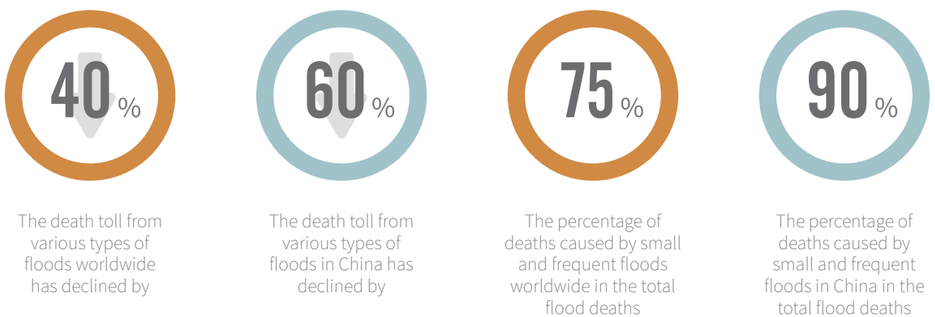


Figure 3 Cumulative loss ratio of large and small disasters in terms of flood death in 30 countries with a high number of flooding deaths from 1976 to 2020

3.1.3 In the past 15 years, flood control in China and the world has effectively reduced the number of deaths due to floods, while small and frequent floods should be paid close attention to

The historical time series show (Figure 4) that flood governance in China and the world has effectively reduced the number of flood deaths, but it is still necessary to continue to pay close attention to small and frequent floods. Although the number of deaths caused by various types of floods in the world and China from 1976 to 2020 has shown no obvious decline or a slight decline, it has shown a continuous decline in the past 15 years (Figure 4 (a)), and the decline has reached approximately 40% and 60% respectively. The number of deaths caused by a single small and frequent flood event has continued to decline in China and globally (Figure 4 (d)), but the number of occurrences has shown an overall upward trend (Figure 4 (e)), resulting in the overall stability of the death toll in China and the world (Figure 4 (b)). Furthermore, in the past 15 years, the percentage of deaths caused by small and frequent floods in the total flood deaths has stabilized at more than 75% worldwide, and it has rapidly increased to more than 90% in China (Figure 4 (c)). These data show that China and the world need to pay closer attention to small and frequent flood events. In addition, the data show that there were 37 incidents in China that caused losses but no deaths (that is, the number of deaths was 0, and the number of people affected was not 0). Among them, 54% of the incidents (20 incidents) occurred after 2000. There were 1,367 incidents that caused losses but no deaths worldwide, and 71% of the incidents (968 incidents) occurred after 2000. This is consistent with the declining frequency of small and frequent flood events in the world and China in the past 15 years, indicating that flood control in China and the world has reduced the number of small and frequent flood disasters to a certain extent.



*The figures above show the data for the last 15 years.

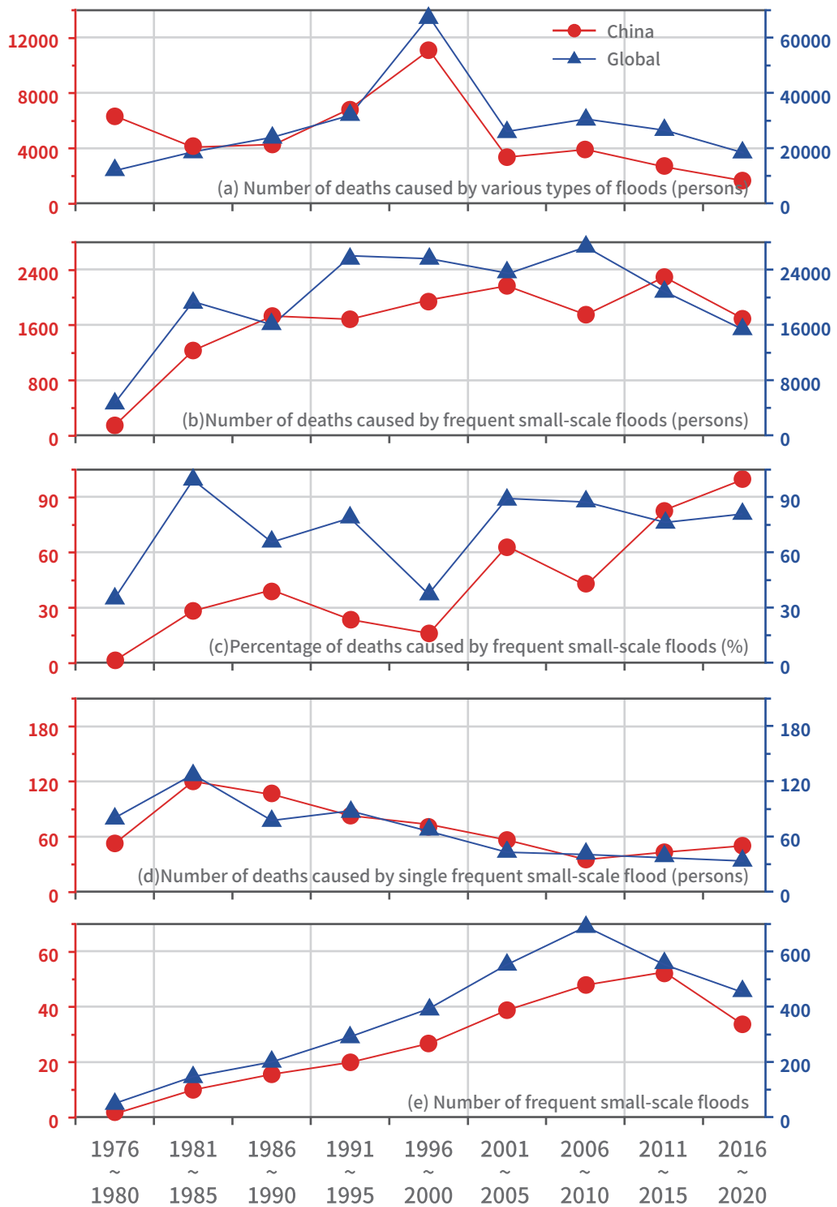


Figure 4 The frequency of floods and the time series of deaths caused by floods from 1976 to 2020 (total number every five years)

3.2 Flood-affected population

In the past 45 years, severe and rare flood events have greatly increased the number of people affected by floods in the world. During the period, among the top 30 countries with the largest number of people affected by floods, approximately 80% of them have recorded a larger cumulative number of people affected by severe and rare flood events than that of small and frequent events. In the past 20 years, flood control in China and around the world has effectively reduced the number of people affected by floods, and flood events of moderate intensity and above should continue to be paid attention to.

3.2.1 The cumulative number of people affected by severe and rare floods in China in the past 45 years is about 1.7 times that of small and frequent floods

EM-DAT statistics show that in the past 45 years (1976-2020), the total number of people affected by floods in China is huge, and the cumulative affected population caused by strong and rare floods is about 1.7 times that of small but frequent floods. From 1976 to 2020, China suffered a total of 308 flood events, causing approximately 2.1 billion people to be affected, of which 240 small and frequent flood events (floods in which the number of affected people did not exceed 16.7 million, grade that occurs once every two years) , 22 moderate flood events (the disaster level is between once every two years and once every twenty years) and 2 severe and rare flood events (flood with more than 190 million people affected, grade that occurs once every twenty years) occurred. 240 small and frequent flood events in China (the orange column in Figure 5) resulted in 270 million people being affected; two severe and rare floods (the red column in Figure 5) occurred in 1991 and 1998, and 210 million people and 240 million people were affected respectively. These figures are approximately equivalent to 1.7 times the total number of people affected by 240 small and frequent flood events (Figure 5, the cumulative loss ratio of large and small disasters, CLR=0.60). In addition, the moderate-intensity flood events (a single flood event in which the number of people affected by a single disaster is between once in 2 years and once in 20 years) are represented by the black columns in Figure 5, which caused approximately 66% of the flood-affected population in China during the study period.

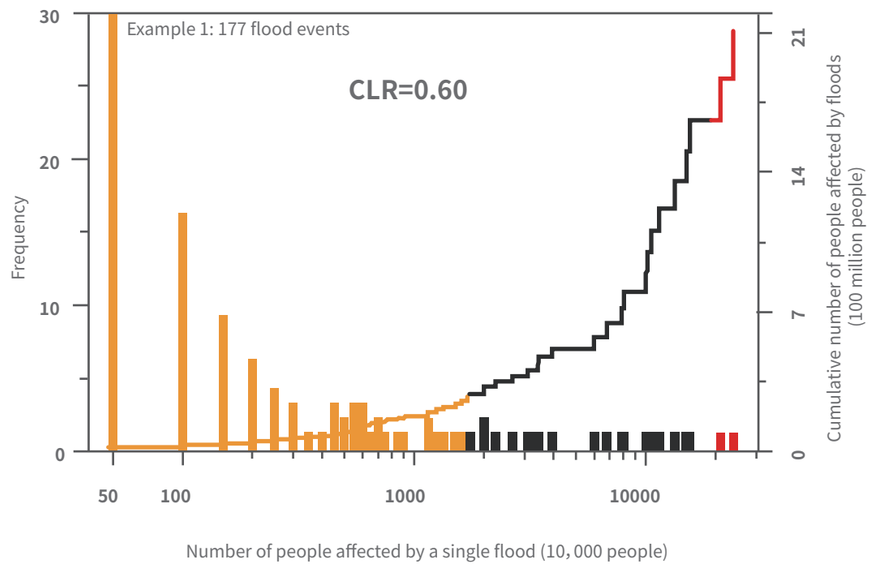


Figure 5 The cumulative flood-affected population in China from 1976 to 2020

3.2.2 Among the top 30 countries with the largest number of people affected by floods around the world in the past 45 years, about 80% of them have recorded a larger cumulative number of people affected by rare high-intensity flood events than that of frequent small-scale flood events

From a global perspective, EM-DAT statistics show that in the past 45 years (1976-2020), the total number of people affected by floods is huge, moreover, the cumulative number of people affected by frequent small-scale floods has exceeded the cumulative number of people affected by rare high-intensity floods. From 1976 to 2020, there were 4,751 flood events worldwide, causing about 3.6 billion people to be affected. Among them, the number of people affected by the 23 floods (once every two years) exceeded 32.7 million people each time, and the number of people affected by the two floods (once every 20 years) exceeded 190 million people each time. The two floods with the largest affected populations occurred in China in 1991 and 1998 (the red column in Figure 6), causing 210 million and 240 million people to be affected respectively. Globally, the cumulative number of people affected by small and frequent flood events (orange columns in Figure 6) is 3.59 times the cumulative number of people affected by two strong and rare floods (Figure 6, cumulative loss ratio of large and small disasters, CLR=3.59). The black columns in Figure 6 represent moderate flood events (in which the number of people affected by a single disaster is between once in 2 years and once in 20 years), which resulted in approximately 44% of the flood affected population in this period.

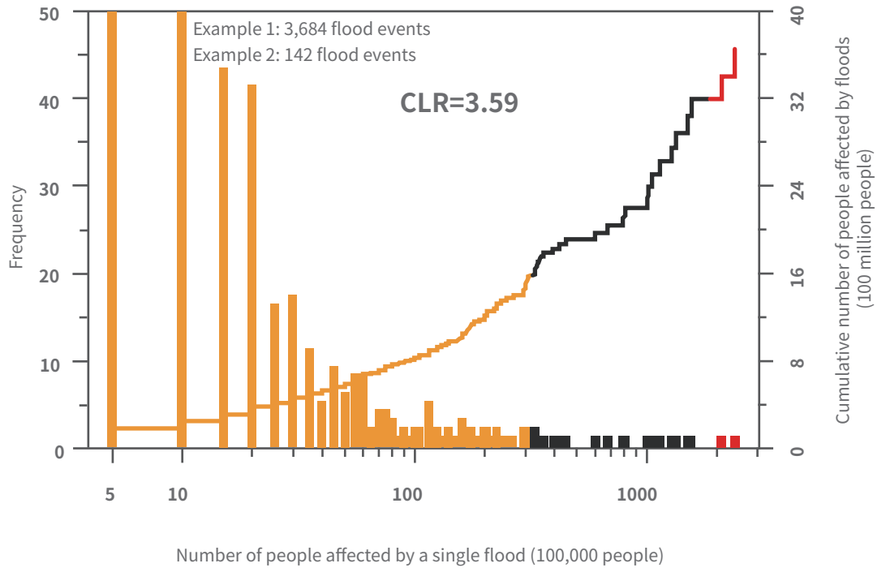


Figure 6 The cumulative flood-affected population worldwide from 1976 to 2020

Nevertheless, from a single country perspective, in about 80% of the 30 countries with the largest flood-affected population in the world, the cumulative number of affected people caused by severe and rare floods has approached or exceeded that of affected people caused by frequent small-scale floods (cumulative loss ratio CLR<1, Figure 7). This shows that in most countries, regardless of the total number of people affected by floods, rare high-intensity flood events are an important category of the affected populations. In addition, in these 30 countries, the cumulative loss ratio of large and small disasters in terms of the flood-affected population is not highly correlated with the total number of people affected by floods. One is that the correlation between the two has not passed the significance test at the p=0.10 level. In countries with a large number of people affected by floods, the cumulative loss ratio of large and small disasters may be larger (such as India) or smaller (such as Bangladesh); in countries with a small number of people affected by floods, the cumulative loss ratio of large and small disasters may be larger (such as Indonesia) or smaller (such as Colombia).

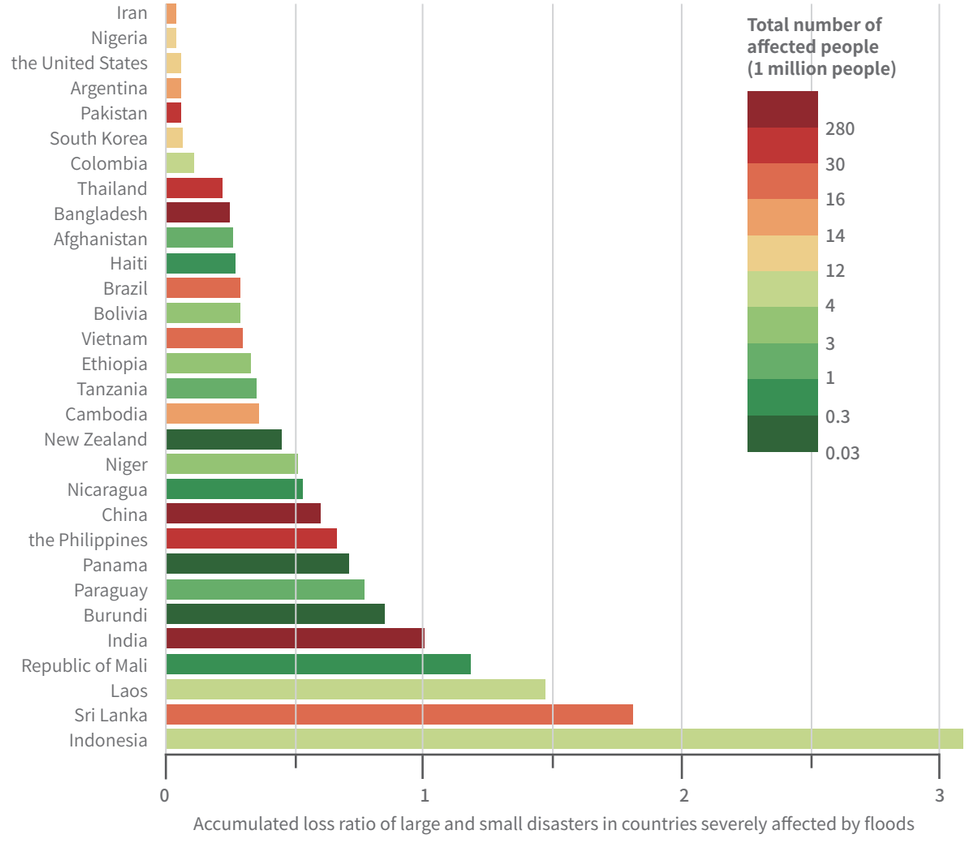


Figure 7 Cumulative loss ratio of large and small disasters in terms of the flood-affected population in 30 countries most severely affected by floods from 1976 to 2020

3.2.3 In the past 20 years, flood control in China and the world has effectively reduced the flood-affected population, and flood events of medium intensity and above should be continuously paid attention to

The historical time series shows (Figure 8) that flood governance in China and around the world has effectively reduced the number of flood-affected people, while flood events of medium intensity and above should be continuously paid attention to. From 2001 to 2020, the number of people affected by various types of floods in the world and China has continued to decrease by more than 50% (Figure 8 (a)). From 1991 to 2020, the number of small and frequent floods has shown an overall upward trend (Figure 8 (e)). The number of people affected by a single event has been basically stable in China, and it has slightly decreased globally (Figure 8 (d)), as a result, frequent small-scale floods have caused an increase in the number of people affected by disasters in China, while the number of people affected by the disasters has been generally stable globally (Figure 8 (b)). In the past 20 years, the percentage of the population affected by small and frequent floods has increased from about 30% to about 60% of the total number of people affected by floods in the world, which shows that frequent small-scale floods have become an important type of contribution to the total number of people affected by floods. However, considering that China's flood-affected population accounts for more than half of the world's total (Figure 8 (a)), and the number of people affected by small and frequent flood events in China accounts for less than 30% of the total flood-affected population (Figure 8 (c)), and considering the analysis of the top 30 countries with the most affected populations in Section 3.2.2 (eighty percent of countries have had a cumulative loss ratio of less than 1), China and the world should continue to pay attention to flood events of medium intensity and above.

The number of people affected by various types of floods in the world and China has continued to decrease by

The percentage of the population affected by small and frequent floods in the global total has increased to

The percentage of the population affected by small and frequent flood events in China in the total is less than

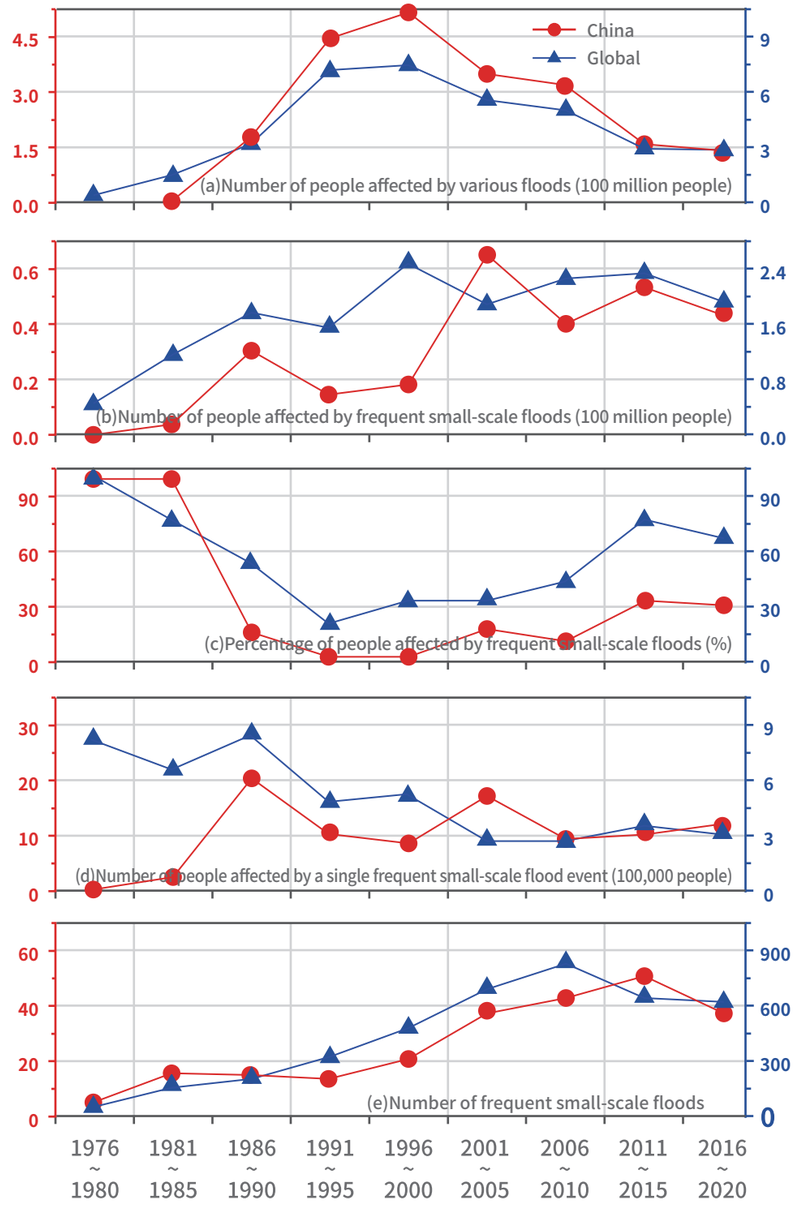


Figure 8 The frequency of floods and the time series of the affected population from 1976 to 2020 (total counts every five years)

3.3 China's flood mitigation efforts have significantly promoted the global flood mitigation process

China is an important member of human flood risk management. China's flood risk management is an important part of global flood risk management. Its progress and effectiveness directly affect the process and results of global flood risk management. The proportion of China's flood deaths in the world's total has dropped from 52% in 1976-1980 to about 20% in 1980-2000, and then to about 11% in 2000-2020, a cumulative drop of about 40% (Figure 9). During the same period, the flood mortality rate in China dropped from 6.6 per million in 1976-1980 to 5.6 per million in 1980-2000, and then to 2.2 per million in 2000-2020, a cumulative decrease of about 67%. The proportion of the flood-affected population in China in the world's total dropped from 62% in 1986-2000 to about 56% in 2000-2020, a cumulative decrease of about 6 percentage points[3] (Figure 9). At the same time, China's flood-affected population rate (population affected by floods as a percentage of the total population) dropped from 32% in 1986-2000 to about 18% in 2000-2020, a cumulative drop of about 14 percentage points. In addition, from 1996-2000 to present, China's flood mortality rate and affected population rate have shown a continuous downward trend. From 1976 to 2020, especially in the past 20 years, the country's flood mitigation work has made positive contributions to the cause of the global flood mitigation and the promotion of realizing disaster risk reduction goals of the United Nations 2030 Agenda for Sustainable Development. Nevertheless, Figure 9 shows that although China's percentage of the world's flood deaths is nearly 9 percentage points lower than China's percentage of the world's population, China's share of the world's flood affected population is nearly 30 percentage points higher than China's share of the world's population. It can be seen that, in addition to further reducing flood deaths in China's future flood mitigation work, special attention should be paid to reducing the flood-affected population in China.

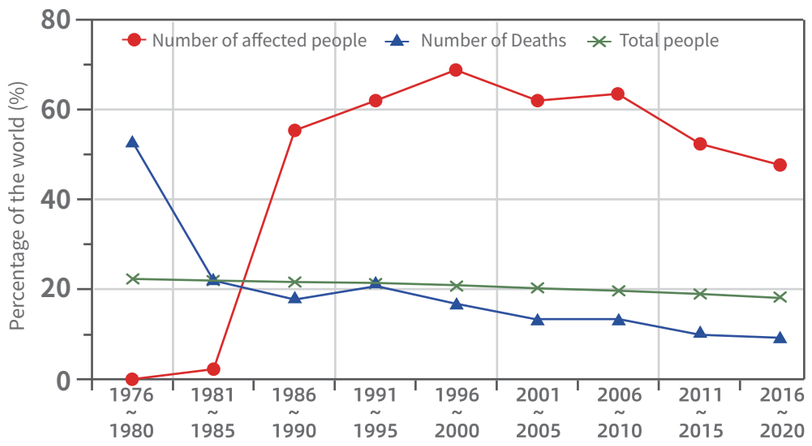


Figure 9 China's flood deaths, flood-affected population, and total population as a percentage of the world's total in 1976-2020 (statistics every five years)

3. Note that the EM-DAT database has a significantly smaller record of the flood-affected population in the world and China before 1986, so only data after 1986 is used here.

4 Conclusion and Enlightenment

Based on the historical records of the impact of floods on the population of countries around the world from 1976 to 2020, using methods such as the cumulative loss ratio of large and small disasters and the statistical distribution of losses, this report analyzes the relative importance of the cumulative losses of the rare high-intensity and frequent low-intensity floods in China and the world. The results show: (1) Among the top 30 countries with the largest flood deaths in the world, the cumulative death toll of frequent low-intensity flood events in half of the countries has exceeded the cumulative death toll of rare high-intensity flood events; (2) Among the top 30 countries with the largest number of people affected by floods in the world, the cumulative number of people affected by rare high-intensity floods in about 80% of the countries has exceeded the cumulative number of people affected by frequent low-intensity floods. (3) Flood control in China and around the world in the past 20 years has effectively reduced the number of flood deaths and affected population.

This study believes that: (1) Flood risk management under the background of global change should reduce flood deaths by paying closer attention to small and frequent flood events, and reduce flood affected population by preventing flood events of medium intensity and above; (2) Simple summary loss statistical indicators, such as extreme loss and total loss, cannot provide sufficient information for regional flood risk management decision making. Therefore, attention should be paid to the detailed analysis of the statistical distribution of loss data; the relative contribution of cumulative losses caused by floods of different intensities within a certain period of time to the total losses can provide new reference information for regional flood risk management decision making; (3) the cumulative contributions of flood events of the same intensity to different flood disaster indicators, such as the number of deaths and the number of people affected by floods, may be inconsistent, thereby providing different flood risk prevention and control reference information; (4) The results of the statistical analysis of disaster data may be affected by the statistical unit scale, therefore, observing, understanding and establishing connections among the characteristics of the disaster data from statistical units at different scales may help to enhance the consistency of flood risk prevention and control policies at different levels.

Special Report 3

Mitigating the impact of floods through comprehensive disaster mitigation: cases of floods in China in 2020

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04

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Mitigating the impact of floods through comprehensive disaster mitigation: cases of floods in China in 2020

1 Foreword

Chinese civilization was bred in the plains and valleys adjacent to the big river. Since the beginning of civilization, flood disasters have plagued China. Since ancient times, China has been carrying out large-scale flood control work. After 2010, the incidence of floods in Chinese cities has increased rapidly, reaching 0.76%[4] in 2015. China's metropolises are mainly located in the middle and lower reaches of the rivers. Due to the huge changes in the way of using land, cities occupy a large amount of water area and wetland, so they are facing severe floods[5].

The losses caused by floods in China are higher than those caused by other disasters, and China's flood losses account for a high proportion of the global flood losses. According to data from the Ministry of Water Resources of the People's Republic of China (2017)[6] and Munich Re (2018)[7], this proportion was close to 10% during the period 1990-2017. Therefore, a full understanding of China's flood disasters, and the implementation of comprehensive disaster reduction measures aimed at flood risks are of far-reaching significance and can effectively guarantee the safety of the public and the long-term benefits of economic development.

In the past 20 years, China has made significant progress in implementing the strategic goals of the Hyogo Framework for Action 2005-2015 and the Sendai Framework for Disaster Risk Reduction 2015-2030. China is working hard to understand current and future risks, and adopt comprehensive disaster reduction measures to reduce and manage these risks, and better adapt to disasters.

Beginning in June 2020, the southern region of China has experienced heavy rainfalls many times, causing sudden rainstorms and floods in many southern regions, especially the Yangtze River Basin. This report sorts out China's flood disaster losses, pays attention to China's flood disasters in 2020, and compares and analyzes with typical historical flood events.

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2 Floods in China

2.1 Flood frequency in China

Affected by the combination of natural geographic conditions and meteorological conditions, floods have become one of the most serious natural disasters in China. In recent years, frequent floods have caused serious casualties and economic losses. According to EM-DAT statistics[8], from 2009 to 2018, there were a total of 102 flood records in China. According to data from the Ministry of Water Resources of the People's Republic of China[9], nearly 370 rivers have experienced over-alert water level floods in the past ten years, and about 24 rivers have floods exceeding historically measured records each year. Almost all provinces have been affected by floods to varying degrees.

Relevant research shows that the incidence of flood disasters in Chinese cities has increased rapidly after 2010, reaching 0.76% in 2015, which means that about 76% of cities across the country had at least one flood in 2015. Most of the disaster-stricken cities in China are concentrated in the central-eastern and southeastern regions, and flood disasters present a spatial pattern in which the south is heavier than the north.

8. Emergency Events Database (EM-DAT). https://emdat.be/
9. Bulletin of Flood and Drought Disasters in China. http://www.mwr.gov.cn/sj/tjgb/zgshzhgb/

2.2 Flood losses in China

Bulletin of Flood and Drought Disasters in China shows that from 2009 to 2018, the national average annual disaster-affected population was 101.6791 million, 773 people died, 570,230 houses collapsed, the area of crops affected was 8,992,019 hectares, and the direct economic loss was approximately USD 344.269 billion, accounting for 0.39% of the GDP. Among them, the disaster affected the most in 2010. The detailed information of the flood damage over the years is shown in Figure 1, where the line chart labels refer to the left axis, and the bar chart labels refer to the right axis.

In the past ten years, the absolute value of direct economic loss caused by floods in China has fluctuated greatly, but the direct economic loss rate has shown a decreasing trend. In terms of impact on population, both the absolute number of affected people and the affected rate have been significantly reduced, which shows that China has put the protection of people's lives in the first place when responding to natural disasters and achieved significant results.

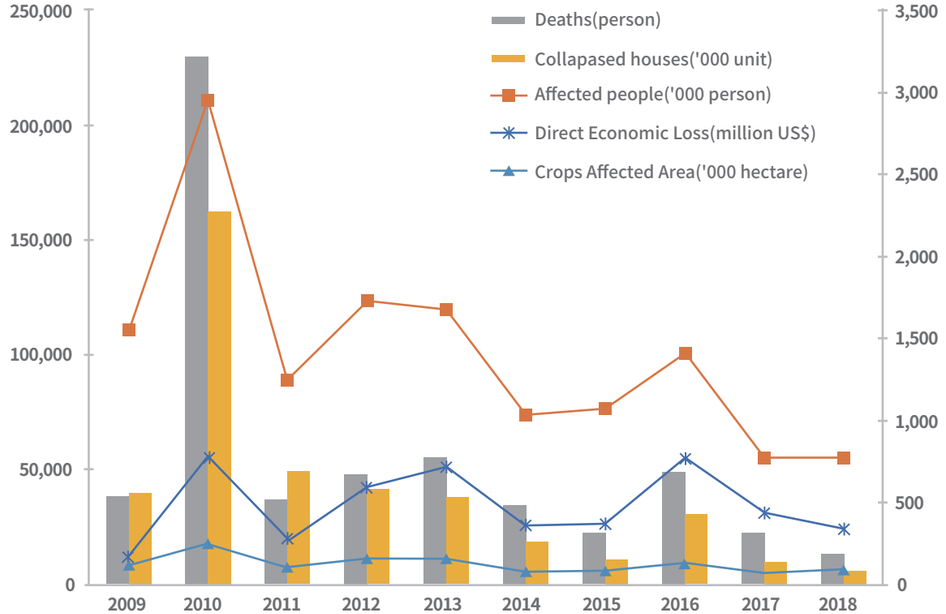


Figure 1 Losses from flood disasters in China from 2009 to 2018

2.3 Comparison of flood damage between China and the world

According to EM-DAT data, the global ranking range of China's population loss from 2009 to 2018 is 1~4, and the ranking range of economic loss is 1~2 (Table 1). Both indicators ranked first in 2012 and 2016. In 2010, China's flood disasters accounted for the largest proportion of absolute population losses, and the smallest in 2009; the largest proportion of absolute economic losses in 2012 and the smallest in 2011. Obviously, these results are partly due to China's huge population and GDP base. If the population loss rate and economic loss rate are used as indicators, the ranking range will be further expanded. The world ranking of China's flood disaster population loss rate fluctuated between 25 and 50 in the past ten years, with an average of about 34. The world ranking of economic loss rate fluctuates between 2 and 13, with an average of about 9 (Table 1). It can be seen that for China, the economic losses caused by floods are more prominent, especially in 2016.

Table 1 Comparison of flood damage between China and the world

Year	Absolute population loss ranking	Population loss as a percentage of the global total	Population loss rate ranking	Absolute economic loss ranking	Economic loss as a percentage of the global total	Economic loss rate ranking
2009	2	5.76%	50	2	17.15%	12
2010	2	22.87%	29	1	36.98%	12
2011	3	10.19%	37	2	15.13%	9
2012	1	17.72%	35	1	58.10%	6
2013	2	6.49%	32	1	30.28%	13
2014	3	13.38%	29	2	26.52%	10
2015	3	8.92%	41	1	33.16%	11
2016	1	18.56%	25	1	55.90%	2
2017	3	7.08%	26	1	41.66%	10
2018	4	8.47%	35	2	23.21%	8

(*Note: The population and economic losses caused by floods are listed in descending order)

3 Floods in southern China in 2020

3.1 Meteorologic analysis

Since June 2020, the southern part of China has experienced heavy rainfalls many times. Heavy rain in many places in the south (especially the Yangtze River Basin) caused sudden floods. In terms of global atmospheric circulation, there are three main reasons: Firstly, China is located between the subtropical high-pressure zone in the western Pacific and the inland high-pressure zone. Affected by El Niño, the western ridge of the western Pacific subtropical high in summer strengthens and extends westward. These circulation anomalies have contributed to more precipitation in the middle and lower reaches of the Yangtze River; secondly, the South China Sea summer monsoon burst earlier this year, and the intensity of cold front moving towards the middle and lower reaches of the Yangtze River was stronger, causing the cold and warm air masses in the south to continue to converge; thirdly, the snow cover area of the Qinghai-Tibet Plateau in winter was obviously larger than usual in 2019-2020. Snow in the plateau in winter changed the thermal conditions of the plateau in spring and summer, indirectly leading to increased convection and precipitation in the middle and lower reaches of the Yangtze River. In general, the regional floods in southern China in 2020 are the result of the combined effects of the subtropical high in the western Pacific, the westerly zone, snow cover on the plateau, and global climate anomalies. The southern rainstorm process has 4 characteristics:

(1) There were days of heavy rain and long duration. From June to July 2020, heavy rain was frequent in southern China, and 66% of cities and counties were hit by heavy rain. The average number of rainstorm days in the southern region was 30% more than the same period in previous years. The heavy rain process lasted for a long time, including June 12 to June 25 (2 weeks), and June 27 to July 12 (16 days). From June 2 to July 12, the Central Meteorological Observatory issued a rainstorm warning for 41 consecutive days. This is the longest warning time since the country started the rainstorm warning service in 2007. The changes in daily average precipitation in the five provinces (Anhui, Jiangxi, Jiangsu, Hunan, and Hubei) in the middle and lower reaches of the Yangtze River in June and July 2020 are shown in Figure 2.

(2) High overlap of rain areas, with heavy cumulative rainfall. The heavy rain from June 27 to July 12 was concentrated in the middle and lower reaches of the Yangtze River. In most areas, precipitation was above 200 mm, and in some areas, precipitation was above 400 mm. Most areas experienced 1-2 times more rain than normal. In June and July 2020, the cumulative precipitation of the five provinces in the middle and lower reaches of the Yangtze River is shown in Figure 3. The accumulated precipitation in northern Jiangxi, southern Anhui, northern Hunan, and southern Hubei all reached 1000 mm, of which high-intensity rainfall was very concentrated in most areas of northern Jiangxi. In June and July 2020, the cumulative rainfall in local areas such as Enshi, Hubei (2,075 mm), Anqing, Anhui (1,864 mm), Huangshan, Anhui (1,824 mm), and Jingdezhen, Jiangxi (1,806 mm) exceeded 1,800 mm. The precipitation in Chongqing, Hubei and Anhui was the highest in the same period in history, and the precipitation in Guizhou, Jiangsu, Shanghai, and Zhejiang was the second highest in the same period in history.

(3) The daily rainfall was heavy. In June 2020, 55 weather stations in China monitored extreme daily precipitation. In July, 103 stations in Anhui, Jiangxi, Hubei, Henan, and Shandong detected extreme daily precipitation events.

(4) The precipitation in some river basins was obviously higher than normal. Since June, the accumulated precipitation in the Yangtze River Basin has reached 528.8 millimeters, 50% more than the same period in previous years, and the largest in the same period since 1961; the accumulated precipitation in the Taihu Lake Basin was 690.1 millimeters, which was twice that of the same period in normal years and the second largest in the same period (second only to that in 1999); the precipitation in the Huaihe River Basin was 436.6 mm, 52% more than the same period in history, ranking second in the same period.

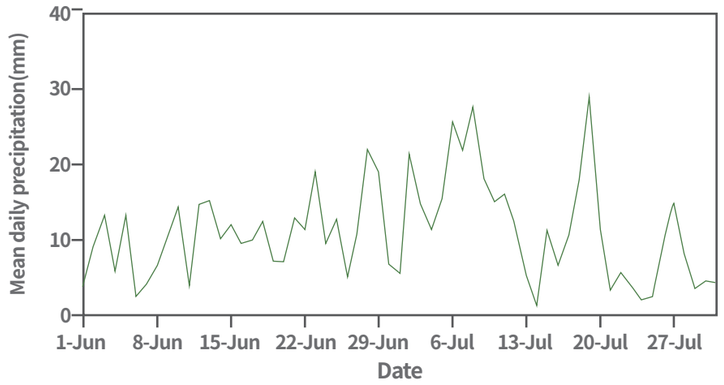


Figure 2 Changes in the average daily precipitation of the five provinces in the middle and lower reaches of the Yangtze River in June and July 2020

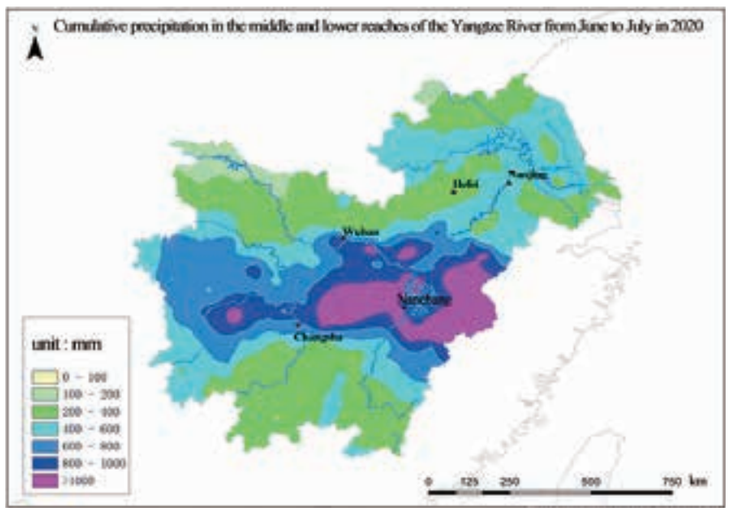


Figure 3 Cumulative precipitation in the middle and lower reaches of the Yangtze River in June and July 2020

3.2 Hydrological analysis

(1) Distribution of rivers and lakes

River network density is an important factor in the risk assessment of flood disasters. The five provinces of Hubei, Anhui, Jiangxi, Hunan, and Jiangsu, as the most severely affected by floods in the south in 2020, all have vast rivers and lakes resources. Although these rivers and lakes can accommodate a certain amount of heavy rainfall during the rainy season, the long-lasting torrential rain process will exceed their limited carrying capacity, which will bring flood disaster risks when the river or lake water level exceeds the warning line. Except for the main streams of the Yangtze River and Han River in Hubei Province, the total length of rivers in the province is 59,200 kilometers, of which 41 are more than 100 kilometers. The Yangtze River flows through 26 counties and cities in the province from west to east, with a total length of 1,041 kilometers. The Han River is the largest tributary in the middle reaches of the Yangtze River, and it flows through 13 counties and cities in Hubei, with a total length of 1,532 kilometers and a drainage area of 62,400 square kilometers. The main rivers in Anhui Province are the Yangtze River, the Huaihe River and the Qiantang River, with a total water area of 206.851 square kilometers. The total length of rivers in Jiangxi Province is 18,400 kilometers, of which the drainage area of the centripetal water system centered on Poyang Lake is 162,200 square kilometers; the total length of rivers in Hunan Province is 90,000 kilometers, of which 17 are large rivers with a drainage area of more than 5,000 square kilometers. Among them, the main ones are Xiangjiang River, Zijiang River, Yuanjiang River and Lishui River. These rivers merge into Dongting Lake and the Yangtze River from south to north along the terrain, forming a complete Dongting Lake water system; the Yangtze River flows for 433 kilometers through Jiangsu Province and the Beijing-Hangzhou Grand Canal flows for 718 kilometers. Two of China's five largest freshwater lakes are located in Jiangsu. Taihu Lake covers an area of 2,250 square kilometers and Hongze Lake has an area of 2,069 square kilometers. In addition, there are more than 290 large and small lakes, including 12 lakes over 50 square kilometers.

(2) Flood water level

Since June 2020, 836 rivers across the country had flooded beyond the warning level. The water level in 269 rivers rose above the guaranteed water level, and water at 78 rivers exceeded the historical record. Dangerous flood conditions emerged in the upper reaches of the Yangtze River and the Yellow River, and the Xijiang and Beijiang in the Pearl River basin, and Taihu Lake basin.

Jiujiang Station in Jiangxi Province is located in the middle reaches of the Yangtze River, with a flood peak water level of 22.81 meters. The highest water level in the station's history was in 1998, reaching 23.03 meters. At 5:30 on July 12, the flood peak water level appeared at the Chenglingji (Qilishan) station of Dongting Lake at 34.58 meters, which exceeded the guaranteed water level by 0.03 meters, which was the sixth highest water level in history. The highest water level in the station was 35.94 meters in 1998. At 20:00 in the evening on July 12, the water level of the flood peak of Poyang Lake at Hukou Station was 22.49 meters, which exceeded the guaranteed water level by 0.01 meters, ranking second in history, only 0.1 meters lower than the highest water level in history on July 31, 1998. At 23:00 in the evening on July 12, the Hankou Station in the middle reaches of the Yangtze River ushered in the flood peak. The water level was 28.77 meters, which was 1.47 meters above the warning water level, second only to 1954, 1998 and 1999, and is the fourth highest water level in history. The highest peak water level in the history of Hankou Station occurred on August 18, 1954, reaching 29.73 meters. At 21:00 on July 13, a flood peak appeared at Datong Station on the lower reaches of the Yangtze River. The water level was 16.24 meters, which exceeded the warning water level by 1.84 meters, the third highest in history. The highest water level in history of Datong Hydrological Station appeared in August 1954, reaching 16.64 meters, and in August 1998, it reached 16.32 meters.

Under the influence of heavy rain in Jinsha River, Jialing River, Wujiang River and the Three Gorges section of the upper reaches of the Yangtze River, the inflow of the Three Gorges Reservoir increased rapidly. It reached 28,100 cubic meters per second by 20:00 on July 15, exceeding 50,000 cubic meters per second at 10:00 on July 17. As of 8:00 on July 18, the water level of the Three Gorges Dam on the Yangtze River was as high as 160.17 meters, with a water intake of 61,000 cubic meters per second and a water output of 33,000 cubic meters per second. At 16:00 on July 17, the water level of the Yichang Hydrological Station was 49.47 meters, and the flow was 33,800 cubic meters per second. The highest water level in the station's history was 54.50 meters on August 17, 1998.

rivers exceeding the warning level in China

rivers exceeding all historical levels

3.3 Socio-economic development in the disaster area

The worst-hit areas in 2020 are Hubei, Anhui, Jiangxi, Hunan and Jiangsu. The total area of these places is 811,900 square kilometers. The total population of the five affected provinces is about 300 million, and the regional GDP is about CNY 25 trillion, accounting for a quarter of the national GDP.

According to statistics from the Ministry of Emergency Management, as of July 28, 54.81 million people were affected by floods in southern China this year, 158 people died, and direct economic losses were CNY 144.4 billion. In 1998, the Yangtze River experienced catastrophic floods in the entire river basin. The death toll from the flood disaster reached 1,526 people and the direct economic loss was CNY 255 billion. Compared with 1998, this year the number of deaths due to disasters is about 1/10 of 1998, and the direct economic loss is about 1/2 of 1998.

As of July 14, the number of people affected by the disaster in Jiangxi Province ranked first among all provinces in the country. The flood disaster that began on July 6 has caused 6.424 million people in the province to be affected, and 654,000 people were urgently transferred and resettled. Hubei Province was the province with the largest area of crop damage and the worst economic loss in China. As of July 14, 1.371 million hectares of crops were damaged in the province. According to preliminary statistics, economic losses amounted to CNY 21.089 billion.

As of July 15, the Ministry of Emergency Management and the Ministry of Finance allocated a total of CNY 1.755 billion in subsidies from the central government. Together with the State Bureau of Grain and Material Reserves, the two ministries allocated 93,000 relief supplies from the central government to support flood relief in the disaster-stricken areas. In addition, the National Comprehensive Fire and Rescue Team dispatched 47,000 person-times to rescue and evacuate 76,000 people in distress.

According to the assessment report of the World Meteorological Organization (WMO, 2020) and the United Nations Intergovernmental Panel on Climate Change (IPCC, 2018), the frequency of heavy rain will increase in the future, and the impact of large-scale floods cannot be underestimated. Therefore, minimizing the losses caused by floods is one of the most pressing issues facing human society in the world today.

54.81 million

Affected population of flood disasters

158

Death toll of flood disasters

144.4 billion CNY

Direct economic losses from flood disasters

3.4 Disaster loss assessment

According to data from the Ministry of Water Resources of China on August 13, 2020, 63.46 million people were affected by floods in 2020, with direct economic losses of CNY 178.96 billion, an increase of 12.7% and 15.5% from the average of the previous five years respectively. As a result of the disasters, 219 people died or went missing, and 54,000 houses collapsed, a decrease of 54.8% and 65.3% from the average of the previous five years respectively. According to the Top 10 Natural Disasters in China in 2020 issued by the Ministry of Emergency Management, the cumulative losses from summer flooding in China in 2020 reached a total of CNY 225.56 billion. Table 2 summarizes the flood disaster losses in some provinces and municipalities in China in 2020. Table 3 lists several typical large-scale flood events in different periods in China. It can be seen that the flood disasters in 2020 have a stronger disaster intensity than previous years, while the absolute value of disaster losses and loss rate have significantly reduced.

Table 2: Statistics of flood disaster loss in some provinces and municipalities in China in 2020

Province	Affected population (10,000 people)	Area of affected crops (Thousand hectares)	Direct economic loss (CNY 100 million)	Statistical time
Anhui	862.89	1024.24	345.11	2020.7.26
Jiangxi	746.8	737.9	245	2020.7.30
Hubei	32.63	1371	210.89	2020.7.14
Hunan	601	54.98	122.9	2020.7.20
Chongqing	63.5	26.7	10.2	2020.7.18
Sichuan	135	25.1	42.3	2020.7.22
Guizhou	51.09	24.4	15.38	2020.8.7

Table 3: Loss statistics of typical flood events in different periods in China

Year	Flood level	Historical direct economic loss(CNY 100 million)	Loss as a percentage of GDP for the year (%)
1998	Catastrophic flood	2551	2.99
2003	Big flood	1300	0.95
2010	Big flood	1976	0.48
2016	Catastrophic flood	1661	0.22
2020	Catastrophic flood	1789	0.18

*The source of flood loss data is different, and it does not completely represent the actual loss under complete statistics. The data is for reference only

From the perspective of disaster system theory, disaster-forming environment and elements at risk, the disaster loss can be evaluated by calculating precipitation, submerged area, altitude, land use, population density, GDP, etc. Take the flood disaster in the Poyang Lake Ecological Economic Zone in Jiangxi Province as a case study.

4 Case study: flooding in Poyang Lake Ecological Economic Zone in Jiangxi Province

Since the 2020 flood season, heavy rainfall has occurred many times in southern China, causing severe floods in the middle and lower reaches of the Yangtze River, the Huaihe River Basin, southwest China, south China, and southeastern coastal areas. From June 1 to July 7, a total of 6 heavy precipitation events occurred in the middle and lower reaches of the Yangtze River. The average rainfall in the Yangtze River Basin was 346.9 mm, the second largest rainfall in the same period since 1961, exceeding the rainfall during the 1998 flood season in China. As of July 28, the flood has affected 54.811 million people in 27 provinces including Jiangxi, Anhui, and Hubei, with 158 dead or missing, and direct economic losses of USD 20.69 billion. Compared with the average level of the same period in the past five years, the number of people affected by the disaster has increased by 23.4%, and the direct economic loss has increased by 13.8%.

4.1 Analysis of disaster intensity

According to experts, subtropical high pressure in 2020 was westward and stronger, resulting in better water vapor conditions, making the rainfall violent, long-lasting and have staying power. Jiangxi Province, one of the main disaster-stricken areas, had an average rainfall of 214 mm since July, the highest in history since 1950. The distribution of precipitation in the province was uneven in time and space, and rainfall has been 60% more than normal since June. Especially since July, the disaster-causing torrential rain has been concentrated in northern Jiangxi. The precipitation in northern Jiangxi cities such as Jingdezhen, Nanchang, Jiujiang and Shangrao reached 5-6 times the average value of the same period in previous years. Heavy rain was mainly concentrated in the Raohe River, Xiuhe River and Poyang Lake areas, with a cumulative rainfall of 300-500mm. Among them, the Poyang Lake Basin was one of the most severely flooded areas in southern China this year. The 24-hour average precipitation and the frequency of heavy rain in Fuliang County (279mm) and Pengze County (264mm) in the basin reached the level of once every 50 years. Among them, the 12-hour and 24-hour heavy rain levels at several meteorological stations exceeded the levels of once every 100 years.

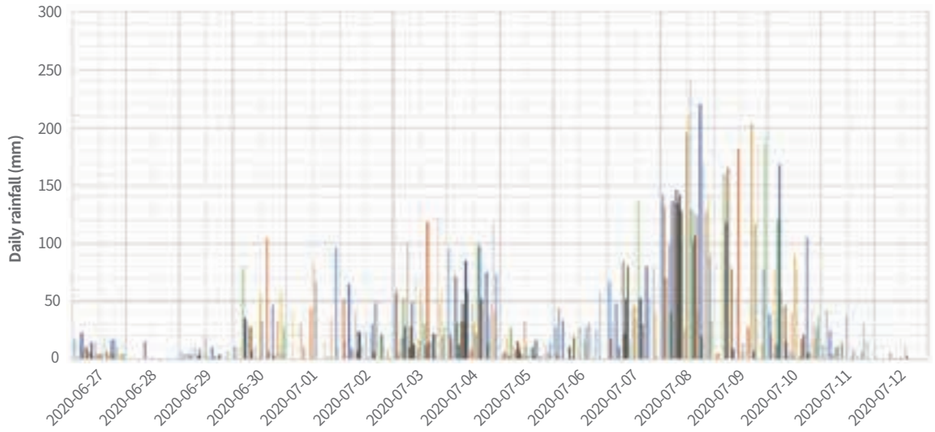


Figure 4 Daily rainfall at 30 weather stations in Poyang Lake Ecological Economic Zone (different color bars represent different stations)

Poyang Lake Ecological Economic Zone experienced a large-scale heavy rainfall process from the end of June, with fierce rain (25-50mm) for 12 consecutive days, heavy rain (50-100mm) for 10 days and torrential rain (100-250mm) for 8 days (Figure 4). The continuous heavy rainfall caused the dike breach of the Triangle Lianwei in Yongxiu County, and 14 dikes in Poyang County were in danger of flooding. The water level of Poyang Station broke through the historical extreme value in 1998. At 22:00 on July 8, the Jiangxi Provincial Hydrological Bureau issued a red flood warning, declaring that the flood control situation was extremely severe.

4.2 Flood hydrological analysis based on remote sensing monitoring

The continuous heavy rainfall caused the water level of rivers in many southern provinces to soar. According to national river water level information on July 12, the water level of 10 hydrological stations on the main streams of the Yangtze River exceeded the alarm. The National Flood Control and Drought Relief Headquarters also upgraded the emergency response for flood control from level three to level two. Among them, Jiangxi was one of the areas where the flood situation was particularly serious. Water at all hydrological stations at Poyang Lake, the largest freshwater lake in China, exceeded warning levels, and at least four hydrological stations have exceeded the historical flood level in 1998. Since July 4, there had been 10 consecutive floods in five rivers and one lake in Jiangxi within a week, 430,000 people were urgently transferred and resettled, and 455,000 hectares of crops were affected. Taking Hukou Station at the entrance of the Yangtze River in the Poyang Lake Basin as an example (Figure 5), the water level at this station had been over-alert since July 6 and continued to rise. On July 11, it reached the second level in history. At 16:00 on the afternoon of July 12, the flood peak water level was 22.49 meters, the highest water level in history, 2.99 meters above the warning line and 4.58 meters higher than the same period in history (17.91 meters). On July 12, the inbound flow reached 25,800 cubic meters per second.

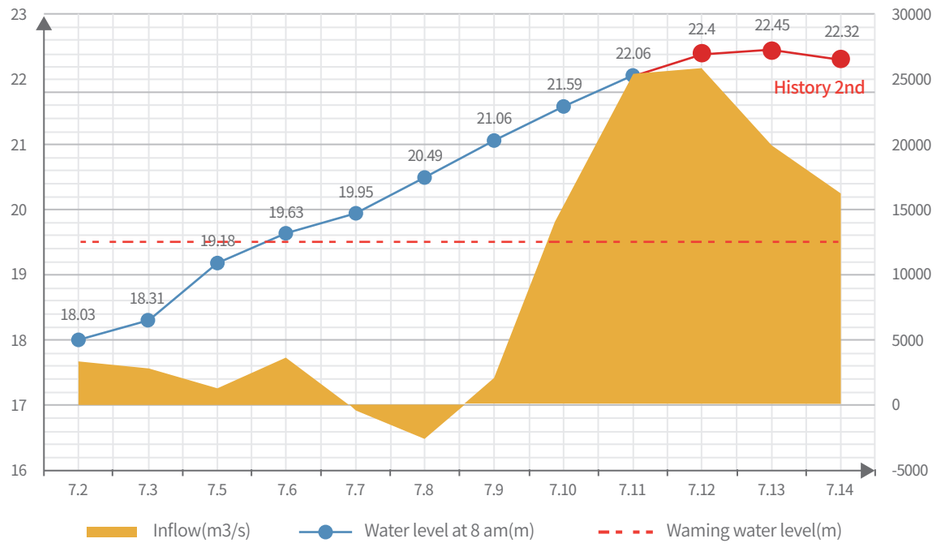
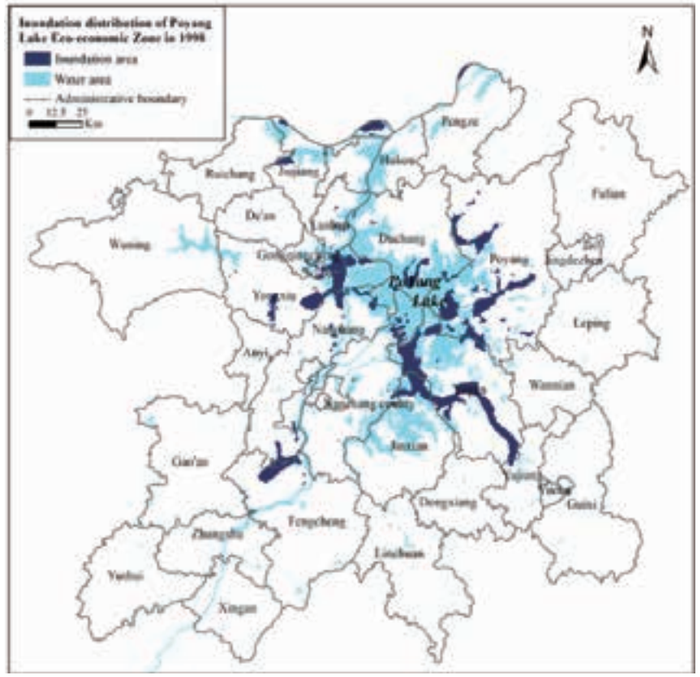


Figure 5 Water level changes at Hukou Station of Poyang Lake

a.



b.

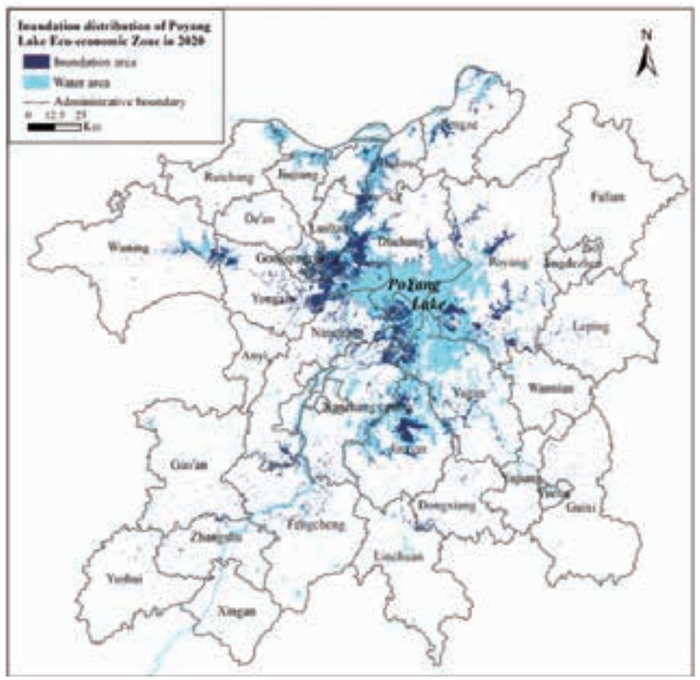


Figure 6 Comparison of flood distribution in Poyang Lake Ecological Economic Zone in 1998 and 2020

Satellite monitoring showed that at 18:00 on July 8, the area of Poyang Lake and nearby waters expanded by 352 km2 compared to July 2, reaching the largest 4,206 km2 in the 10 years. Wetlands which are located at the entrance of the five major tributaries were flooded in large areas. The Sentinel-1 satellite remote sensing image (Figure 6.b) from July 2 to July 14 was used to get the changing area of the water body in the Poyang Lake Ecological Economic Zone. Compared with the flood inundation in 1998 (Figure 6.a), there are two characteristics of the distribution of flood inundation in 2020: 1) Compared with 1998, the distribution of inundation in 2020 is wider; 2) Compared with 1998, the degree of inundation and fragmentation in 2020 is higher. From the first feature and the previous hydrological analysis, in the Poyang Lake basin, the overall disaster intensity in 2020 was stronger than in 1998, but it did not cause large-scale regional flooding similar to 1998. Table 4 shows some basic information about the main disaster-stricken areas (Jiangxi, Hunan, and Hubei) that have suffered flooding events in the past five years. From the crop-affected area and population of the three provinces, it can be seen that the intensity of floods in 2020 was stronger than in the past, and the emergency response issued by the Yangtze River Flood Control and Drought Relief Headquarters has reached the highest level I for the first time in the past five years, while the direct economic loss estimate was smaller than that of previous disasters, especially when compared with the same catastrophic flood events (such as 2016 and 1998 in Table 3). Combining this flood control and anti-flood work, it can be speculated that the reason for this phenomenon is: the strengthening of flood control and anti-flood infrastructure and the advancement of emergency measures effectively blocked the development of floods, and caused floods fragmentation, thereby greatly reducing economic losses from flood disasters.

Table 4 Losses and emergency situations of flood events in the past five years (taking Jiangxi, Hunan, and Hubei provinces as the main statistical objects)

Year	Area of affected crops (thousand hectares)	Affected population (10,000 people)	Direct economic loss (CNY 100 million)
2016	2645	2965	928
2017	132	211	22
2018	173	204	23
2019	782	1037	325
2020	2095	1936	599

*The data come from the National Disaster Reduction Center of China. The data is for reference only and does not fully represent the total loss.

Appendixes

Appendixes

05

Appendix I Top 50 natural disasters in terms of global deaths and direct economic losses from 1990 to 2020

Top 50 natural disasters in terms of global deaths from 1990 to 2020

No.	Time	Countries or regions affected	Disaster type	Number of deaths (persons)	Direct economic losses (USD 0.1 billion, current year prices)
1	2010/1/12	Haiti	earthquake	222570	80
2	2004/12/26	Indonesia	earthquake	165708	44.516
3	1991/4/29-5/10	Bangladesh	storm	138866	17.8
4	2008/5/2-3	Myanmar	storm	138366	40
5	2008/5/12	China	earthquake	87476	850
6	2005/10/8	Pakistan	earthquake	73338	52
7	2010/6/-2010/8/	Russia	extreme heat	55736	4
8	1990/6/21	Iran	earthquake	40000	80
9	2004/12/26	Sri Lanka	earthquake	35399	13.165
10	1999/12/15-12/20	Venezuela	flood	30000	31.6
11	2003/12/26	Iran	earthquake	26796	5
12	2003/7/16-8/15	Italy	extreme heat	20089	44
13	2001/1/26	India	earthquake	20005	26.23
14	2010/2/-2011/11/	Somalia	drought	20000	0
15	2011/3/11	Japan	earthquake	19846	2100
16	2003/8/1-8/20	France	extreme heat	19490	44
17	1999/8/17	Turkey	earthquake	17127	200
18	2004/12/26	India	earthquake	16389	10.228
19	2003/8/1-8/11	Spain	extreme heat	15090	8.8
20	1998/10/25-11/8	Honduras	storm	14600	37.936
21	1999/10/28-10/30	India	storm	9843	25
22	1993/9/29	India	earthquake	9748	2.8
23	2003/8/-2003/8/	Germany	extreme heat	9355	16.5
24	2015/4/25	Nepal	earthquake	8831	51.74
25	2004/12/26	Thailand	earthquake	8345	10
26	2013/11/8	The Philippines	storm	7354	100
27	2020/6-8	The United Kingdom, France, Belgium, the Netherlands	extreme temperature	6340	0
28	2013/6/12-6/27	India	flood	6054	11
29	1991/11/5-11/8	The Philippines	storm	5956	1
30	2006/5/26	Indonesia	earthquake	5778	31
31	1995/1/17	Japan	earthquake	5297	1000
32	1998/5/30	Afghanistan	earthquake	4700	0.1
33	2018/9/28	Indonesia	earthquake	4340	14.5
34	2007/11/15-11/19	Bangladesh	storm	4234	23
35	1997/11/2-11/4	Vietnam	storm	3682	4.7
36	1998/7/1-8/30	China	flood	3656	300
37	1998/10/25-11/8	Nicaragua	storm	3332	9.877
38	2015/6/29-8/9	France	extreme heat	3275	0
39	2010/4/14	China	earthquake	2968	5
40	1998/6/9-6/11	India	storm	2871	4.69
41	1996/6/30-7/26	China	flood	2775	126
42	2004/9/17-9/18	Haiti	storm	2754	0.5
43	2003/8/-2003/8/	Portugal	extreme heat	2696	0
44	2004/5/23-6/1	Haiti	flood	2665	0
45	1998/5/26	India	extreme heat	2541	0
46	1992/12/12	Indonesia	earthquake	2500	1
47	1990/7/16	The Philippines	earthquake	2412	3.696
48	1998/2/4	Afghanistan	earthquake	2323	0.1
49	1997/10/19-11/17	Somalia	flood	2311	0
50	2003/5/21	Algeria	earthquake	2266	50

Top 50 natural disasters in terms of global direct economic losses from 1990 to 2020

No.	Time	Countries or regions affected	Disaster type	Number of deaths (persons)	Direct economic losses (USD 0.1 billion, current year prices)
1	2011/3/11	Japan	earthquake	2100	19846
2	2005/8/29-9/19	The United States	storm	1250	1833
3	1995/1/17	Japan	earthquake	1000	5297
4	2017/8/25-8/29	The United States	storm	950	88
5	2008/5/12	China	earthquake	850	87476
6	2017/9/20	Puerto Rico	storm	680	64
7	2017/9/10-9/28	The United States	storm	570	58
8	2012/10/28	The United States	storm	500	54
9	2011/8/5-2012/1/4	Thailand	flood	400	813
10	1998/7/1-8/30	China	flood	300	3656
10	2010/2/27	Chile	earthquake	300	562
10	2008/9/12-9/16	The United States	storm	300	82
10	1994/1/17	The United States	earthquake	300	60
14	2004/10/23	Japan	earthquake	280	40
15	1992/8/24	The United States	storm	265	44
16	2019/10/10-10/17	The United States	wildfire	250	3
17	2016/6/28-7/13	China	flood	220	289
18	2008/1/10-2/5	China	extreme low temperature	211	129
19	1999/8/17	Turkey	earthquake	200	17127
19	2016/4/16	Japan	earthquake	200	49
19	2012/6/-2012/12/	The United States	drought	200	0
22	2010/5/29-8/31	China	flood	180	1691
22	2004/9/15-9/16	The United States	storm	180	52
24	2019/10/12-10/17	Japan	storm	170	99
24	2020/5/21-7/30	China	flood	170	280
26	2018/11/8-11/16	The United States	wildfire	165	88
27	2014/9/	India	flood	160	298
27	2018/10/10-10/11	The United States	storm	160	45
27	2005/9/23-10/1	The United States	storm	160	10
27	2004/8/13	The United States	storm	160	10
31	2012/5/20	Italy	earthquake	158	7
32	2011/2/22	New Zealand	earthquake	150	181
32	2020/5/20	India, Bangladesh	storm	150	116
32	1995/8/1-9/8	Korea	flood	150	68
35	2005/10/24	The United States	storm	143	4
36	1999/9/21	China	earthquake	141	2264
37	2011/5/20-5/25	The United States	storm	140	176
37	2018/9/12-9/18	The United States	storm	140	53
39	1994/1/-1994/12/	China	drought	138	0
40	2020/8/27-8/28	The United States	storm	130	33
40	2017/10/8-10/20	The United States	wildfire	130	30
42	2013/5/28-6/18	Germany	flood	129	4
43	1996/6/30-7/26	China	flood	126	2775
44	2018/9/4-9/5	Japan	storm	125	17
44	2007/7/16	Japan	earthquake	125	9
46	1993/6/24-8/23	The United States	flood	120	48
47	2002/8/11-8/20	Germany	flood	116	27
48	2011/4/22-4/29	The United States	storm	110	354
48	2020/8/16-10/1	The United States	wildfire	110	32
48	2004/9/5	The United States	storm	110	47

Appendix II Top 30 flood disasters in terms of global deaths and direct economic losses in 2020

World's top 30 flood disasters in the death toll in 2020

No.	Countries or regions affected	Number of deaths (persons)	Direct economic losses (USD 0.1 billion, current year prices)
1	India	1922	75
2	Nepal	448	1
3	Pakistan	410	15
4	Kenya	285	0.1
5	China	280	170
6	Bangladesh	257	5
7	Afghanistan	212	0
8	Sudan	155	2.5
9	Nigeria	155	1
10	India	152	40
11	Indonesia	105	0.1
12	China	92	48
13	Japan	82	58
14	Niger	73	0.1
15	Rwanda	72	0
16	Pakistan	66	0
17	Brazil	61	3
18	Brazil	60	0.75
19	Afghanistan	56	0
20	DR Congo	52	0
21	Indonesia	44	0
22	Korea	42	4.2
23	Madagascar	40	0
24	Egypt	40	0.76
25	South Africa	31	0
26	Angola	30	0
27	Nigeria	30	0
28	India	29	0.1
29	Thailand	29	0.5
30	Tanzania	29	0

World's top 30 flood disasters in direct economic losses in 2020

No.	Countries or regions affected	Number of deaths (persons)	Direct economic losses (USD 0.1 billion, current year prices)
1	China	280	170
2	India	1922	75
3	Japan	82	58
4	China	92	48
5	India	152	40
6	The United States	1	21
7	Australia	2	20
8	Pakistan	410	15
9	Iran	21	15
10	Canada	1	13
11	Australia	1	12
12	Iran	4	8.08
13	Israel	7	5.8
14	Bangladesh	257	5
15	Korea	42	4.2
16	Brazil	61	3
17	Sudan	155	2.5
18	Turkey	16	2.5
19	The United States	0	1.75
20	Ukraine	3	1.54
21	Nepal	448	1
22	Nigeria	155	1
23	Iraq	8	1
24	The United States	8	1
25	The United States	1	1
26	Romania	3	0.85
27	Egypt	40	0.76
28	Brazil	60	0.75
29	Brazil	21	0.75
30	New Zealand	0	0.71

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