2024 GLOBAL NATURAL DISASTER ASSESSMENT REPORT

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Executive Summary

Compared with the average for the last 30 years (1994-2023), the major natural disasters in 2024 showed an 8% decrease in frequency, a 74% reduction in fatalities, a 42% smaller affected population, and a 49% increase in direct economic losses. Among these disasters, floods were the most frequent, with a total of 128 times. Compared to the average for the last 30 years, the frequency of such events decreased by 15%, and the affected population dropped by approximately 54%, although the largest at 48.8424 million. Storms caused the highest direct economic losses, amounting to USD 172.591 billion. Seismic activities decreased, resulting in 602 deaths, representing a 98% reduction in fatalities. Wildfires saw a 74% increase in fatalities though direct economic losses fell by 9%. Landslides occurred more frequently, with fatalities spiking 172% and the affected population rising by a factor of 14, alongside a 9% increase in direct economic losses. Regionally, Asia recorded the most disaster events, totaling 130, followed by Africa and South America. It also accounted for the highest number of deaths due to disasters globally, followed by Africa. North America suffered the highest economic losses, with Asia in second place. Natural disasters predominantly struck economically underdeveloped countries, mainly involving extreme temperatures and floods.

Special Report 1 shows that in 2024, natural disasters in China were primarily caused by floods, geological hazards, typhoons, hailstorms, low-temperature freezing weather, and heavy snowfall, while other disasters such as droughts, earthquakes, forest and grassland fires, and sandstorms also occurred to varying degrees. Compared to the average of the last 10 years (2014-2023), the number of affected people, deaths and missing persons, and collapsed houses due to disasters decreased by 36.8%, 12.1%, and 69.5% respectively, while direct economic losses increased by 12.1%. Compared to 2023, the number of affected people and collapsed houses in China declined by 1.4% and 69.2% respectively, but the number of deaths and missing persons due to disasters and direct economic losses increased by 23.9% and 16.2% respectively.

Special Report 2 focuses on extreme heat events, highlighting that the Middle East, as one of the regions with the highest global climate risks, exhibits significant characteristics of systemic, compound, and cross-border transmission. It grapples long-term with multiple threats such as extreme heat, water scarcity, severe sandstorms, and rising sea levels, creating cross-border spillover effects through ecological chains, trade networks, and geopolitical channels. Currently, the climate risks in the Middle East are deeply intertwined with regional governance deficiencies and socio-economic conflicts, forming a vicious cycle of "environmental degradation-resource competition-security instability", which poses multifaceted challenges to sustainable development.

Special Report 3 concentrates on cross-border disaster events, analyzing the cross-regional and cross-industry economic impacts of the Super Typhoon Yagi on China and neighboring Southeast Asian countries. Through a systematic assessment of the cascading transmission paths of disaster losses, it was found that the indirect economic losses caused by Typhoon Yagi have surpassed regional boundaries, generating systemic spillover effects through global supply chain networks. This indicates that the spatial vulnerability of modern industrial chains is significant, wherein the dominant factors in the transmission of disaster impacts have shifted from geographical proximity to multiple dimensions such as trade linkages, industrial coupling, and transport connectivity. Future disaster risk management therefore needs to break through traditional regional limitations, establishing a global climate resilience collaborative mechanism anchored in global supply chains, transportation chains, and trade chains.

8% ↓ Major natural disasters in 2024 showed decrease in frequency

74% ↓ Reduction in fatalities

42% ↓ Smaller affected population

49% ↑ Increase in direct economic losses

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General Report
Global Natural Disasters in 2024

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1

Overview of global natural disasters in 2024

In 2024, a total of 309 major natural disasters occurred globally, affecting 122 countries and regions. Among them, 128 were caused by floods, with the highest frequency, accounting for 41.42%; 87 caused by storms (including typhoons, hurricanes, etc.), accounting for 28.16%; 33 by landslides, accounting for 10.68%; 20 by wildfires, accounting for 6.47%; 13 by earthquakes, accounting for 4.21%; 11 by drought, accounting for 3.56%; 11 by extreme temperatures, accounting for 3.56%; and 6 by volcanic disasters, accounting for 1.94% (Table 1 and Figure 1).

Table 1 The Frequency and losses of natural disasters worldwide in 2024

Type of disaster	Frequency (time)/%	Fatalities (persons)/%	Population affected (tens of thousands)/%	Direct economic losses (USD 0.1 billion)/%
Flood	128/41.42	5883/35.12	4884.24/29.21	327.67/13.54
Storm	87/28.16	2582/15.41	4792.4/28.66	1725.91/71.33
Earthquake	13/4.21	602/3.59	78.39/0.47	181.3/7.49
Drought	11/3.56	0/0.0	2947.8/17.63	133.32/5.51
Landslide	33/10.68	2259/13.49	356.03/2.13	3.45/0.14
Wildfire	20/6.47	170/1.01	13.84/0.08	47.8/1.98
Extreme temperatures	11/3.56	5247/31.32	3638.04/21.76	0.0/0.0
Volcanic eruption	6/1.94	10/0.06	9.55/0.06	0.0/0.0
Total	**309/100.0**	**16753/100.0**	**16720.3/100.0**	**2419.46/100.0**

(Note: The global natural disaster data come from the EM-DAT of the Université catholique de Louvain (UCLouvain), Belgium; and the time period is from 1 January, 2024 to 31 December, 2024, and the data was download on 17 April, 2025, the same hereinafter. Data of 0 indicates low or missing values, the same below.)

In 2024, a total of 16,753 people were killed by major natural disasters worldwide. Among all disasters, floods caused the highest number of fatalities (5,883), accounting for 35.12% of the total. This was followed by extreme temperature events (both heat and cold), which resulted in 5,247 fatalities (31.32%), storms with 2,582 fatalities (15.41%), landslides with 2,259 (13.49%), earthquakes with 602 (3.59%), wildfires with 170 (1.01%), and volcanic activities with 10 (0.06%).

A total of 167.203 million people were affected by natural disasters globally in 2024. Floods also affected the largest population (48.8424 million people, 29.21%), followed closely by storms (47.9240 million, 28.66%). Extreme temperature events affected 36.3804 million people (21.76%), while droughts impacted 29.4780 million (17.63%). The populations affected by landslides, earthquakes, wildfires, and volcanic activity were significantly smaller, at 3.5603 million (2.13%), 783,900 (0.47%), 138,400 (0.08%), and 95,500 (0.06%), respectively.

A total of USD 241.946 billion in direct economic losses were caused by natural disasters worldwide in 2024. Storms inflicted the greatest economic losses, amounting to USD 172.591 billion and constituting 71.33% of the total. Floods ranked second, with economic losses of USD 32.767 billion (13.54%), followed by earthquakes at USD 18.13 billion (7.49%). Droughts caused USD 13.332 billion in losses (5.51%), wildfires USD 4.78 billion (1.98%), and landslides USD 345 million (0.14%).

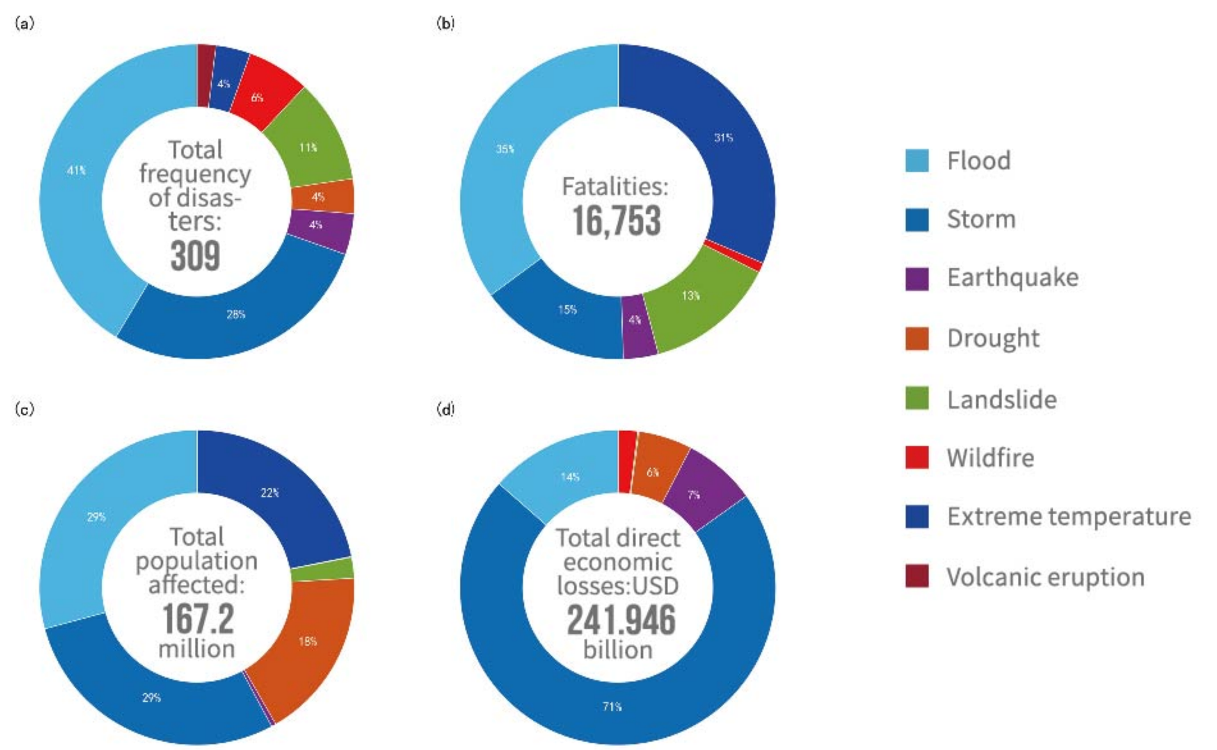


Figure 1 Breakdown of frequency and losses per disaster type worldwide in 2024

2

Characteristics of global natural disasters in 2024

2.1

Notable decline in disaster-related fatalities but an increase in direct economic losses

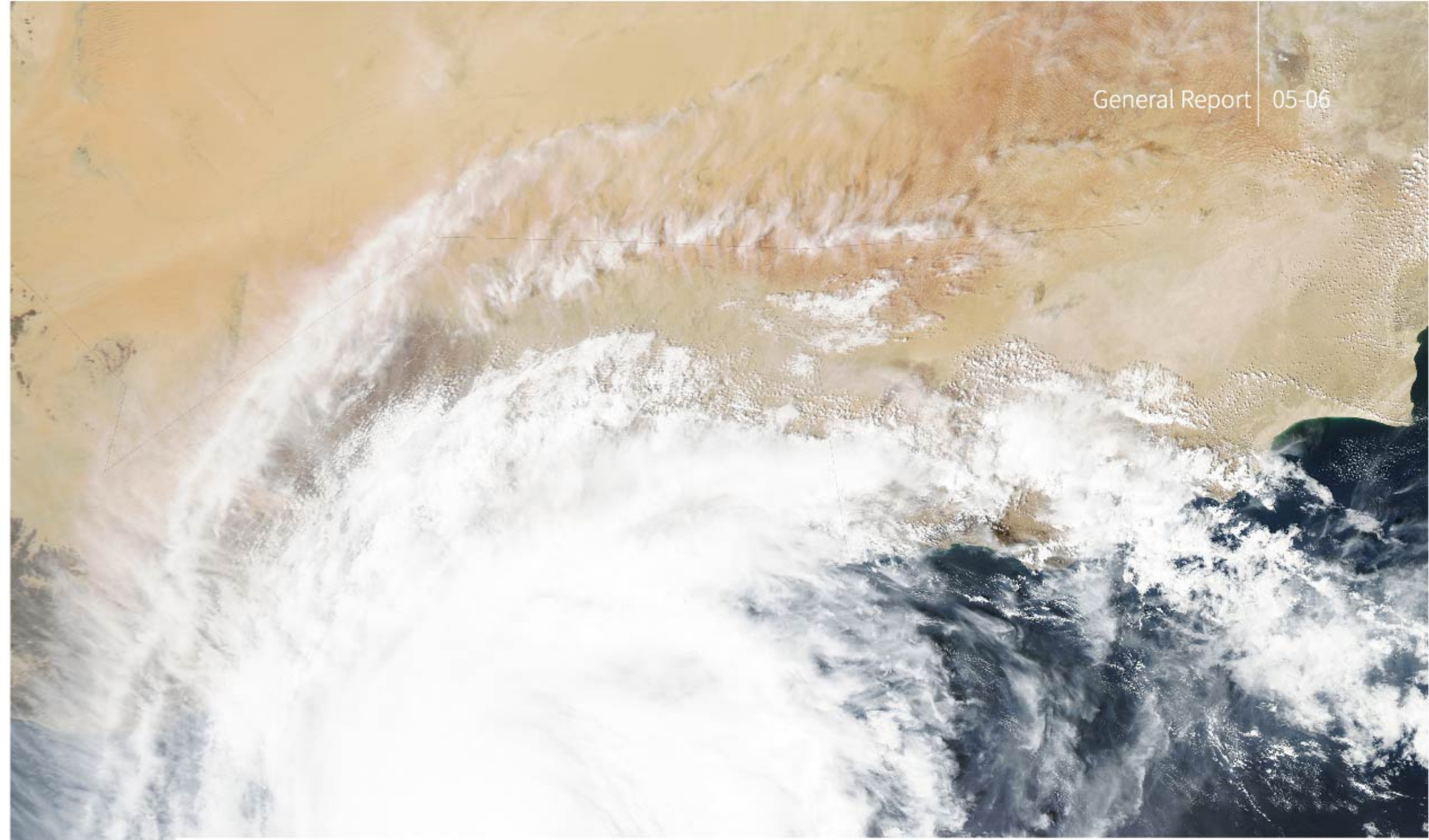
In 2024, a total of 309 major natural disasters occurred worldwide, resulting in 16,753 fatalities, affecting 167.20 million people, and causing direct economic losses of USD 241.9 billion. Compared with the average for the last 30 years (1994-2023), the frequency of major natural disasters was 8% less in 2024, the death toll was 68% less, the affected population was 14% less, but the direct economic loss was 49% higher. Compared to the average of the past decade (2014-2023), 2024 saw a 4% decrease in the frequency of major natural disasters, a 21% reduction in fatalities, a 13% increase in the number of affected population, and a 39% rise in direct economic losses (Figure 2). Although catastrophes in 2024 were less frequent and severe overall than the historical (10-and 30-year) averages, they resulted in higher direct economic losses. In 2024, there were three natural disasters worldwide that resulted in over 1,000 fatalities, which is lower than the average of the past 30 years. No natural disasters with over 10,000 fatalities occurred (21 such disasters were recorded in the past 30 years). In 2024, there were four natural disasters worldwide with direct economic losses of more than USD 10 billion each, slightly higher than the annual average for the last 30 years, and one disaster that caused direct economic losses exceeding USD 50 billion. There have been eight disasters exceeding USD 50 billion at a time in the past 30 years, three of which exceeded USD 100 billion.

8% — The frequency was 8% less

68% — The death toll was 68% less

14% — The affected population was 14% less

49% — The direct economic loss was 49% higher



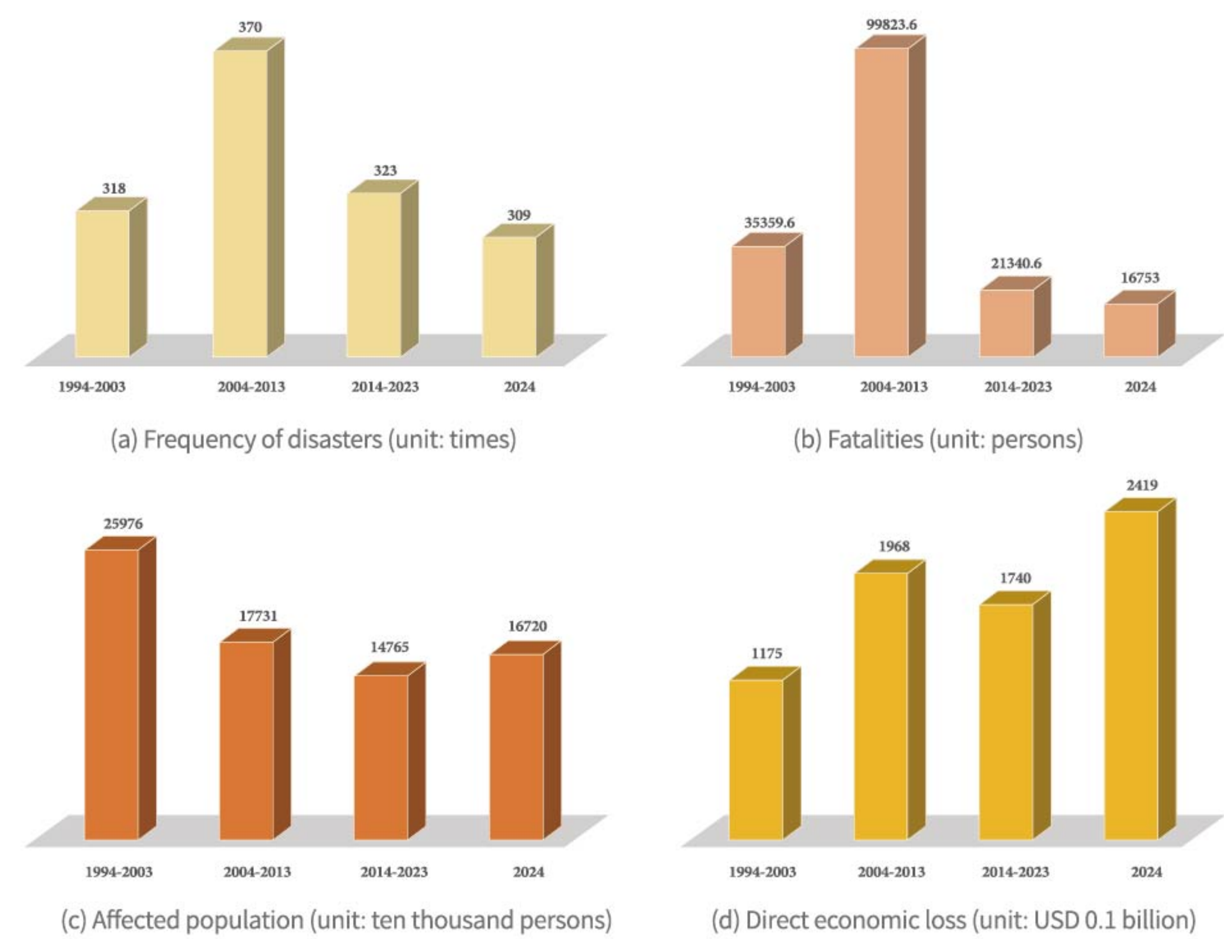


Figure 2 Global average annual natural disaster losses, 1994- 2023 vs. 2024

(Note: The direct economic losses from 1994 to 2023 are measured at the price level of 2023, and those of 2024 are measured at the price level of the current year.)

2.2 Floods were the most frequent types of disasters, resulting in the highest numbers of fatalities and affected population

In 2024, a total of 128 major floods occurred worldwide, accounting for 41% of the total number of major disasters; fatalities caused by floods reached 5,883, approximately 35% of the total deaths; the affected population reached 48.84 million, accounting for 29%; and the direct economic losses were USD 32.8 billion. Compared to the average for the last 30 years (1994-2023), the frequency of floods in 2024 decreased by 14%, the number of fatalities dropped by 14%, the affected population was approximately 47% less, and the direct economic losses were 13% lower. Compared to the average for the last 10 years (2014-2023), floods in 2024 occurred 17% less frequently and resulted in 11% lower direct economic losses. However, the death toll was 23% higher and the affected population was 27% larger (Figure 3). In 2024, there were no floods with a death toll exceeding 1,000, and only one flood with a death toll exceeding 500 (in Chad, Africa).

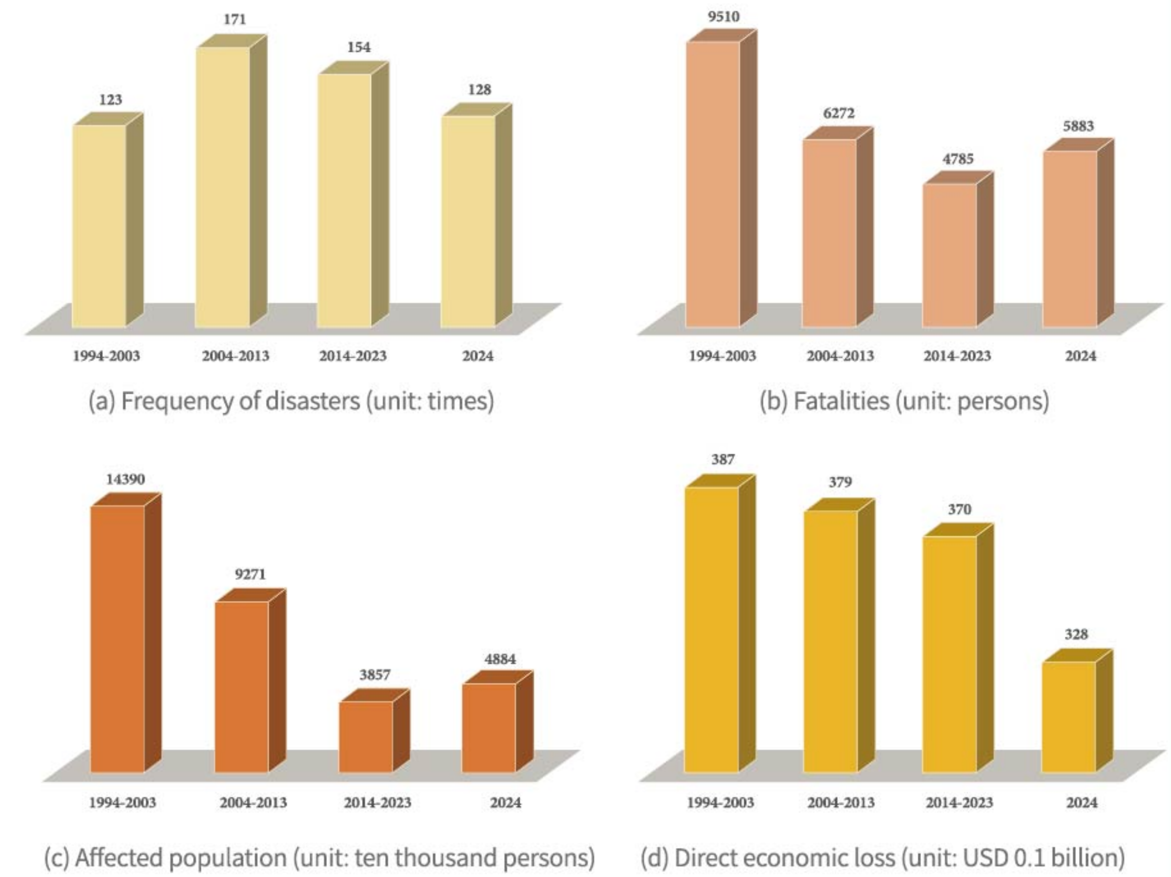


Figure 3 Global average annual flood disaster losses, 1994-2023 vs. 2024

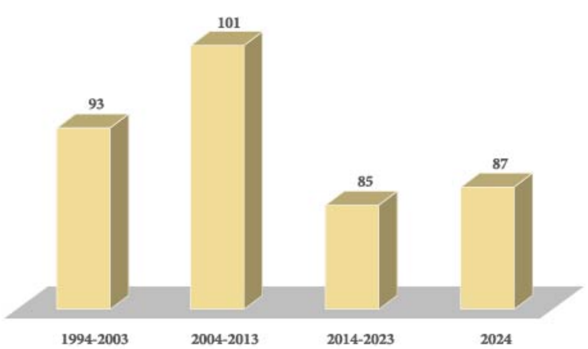
(Note: The direct economic losses from 1994 to 2023 are measured at the price level of 2023, and those of 2024 are measured at the price level of the current year.)

2.3 Prominent and growing proportion of direct economic losses from storms, along with higher affected population

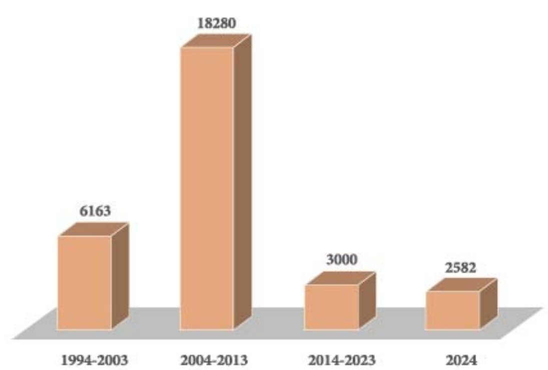
In 2024, a total of 87 major storms occurred worldwide, accounting for 28% of the total major disasters; they resulted in 2,582 deaths, accounting for 15%, and affected 47.92 million people, accounting for 29%; the direct economic losses reached USD 172.6 billion, accounting for 71%. Compared with the average for the last 30 years (1994-2023), storm disasters in 2024 showed a 6% decrease in frequency, a 71% reduction in fatalities, a 51% increase in the number of people affected, and a 138% rise in direct economic losses. Compared with the average for the last 10 years (2014-2023), the frequency of storms in 2024 increased by 2%, while fatalities decreased by 14%, the affected population rose by 69%, and direct economic losses were 70% higher (Figure 4).

2.4 Low frequency of major earthquakes, resulting in minimal fatalities and affected population

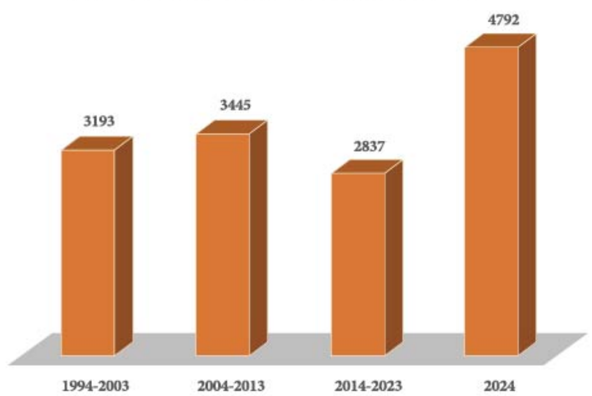
In 2024, there were 13 major earthquake disasters worldwide, accounting for 4% of the total number of major disasters of the year. Fatalities from earthquakes accounted for about 3.6% of the total fatalities from natural disasters; the affected population accounted for about 0.5%; and the direct economic losses accounted for about 7.5%. Compared to the average for the last 30 years (1994-2023), earthquakes in 2024 showed a 51% decrease in frequency, a 98% reduction in fatalities, an 86% smaller affected population, and a 49% drop in direct economic losses. Compared to the average for the last 10 years (2014-2023), earthquake frequency in 2024 was 47% lower, fatalities were 93% fewer, the affected population decreased by 81%, while direct economic losses increased by 45% (Figure 5).



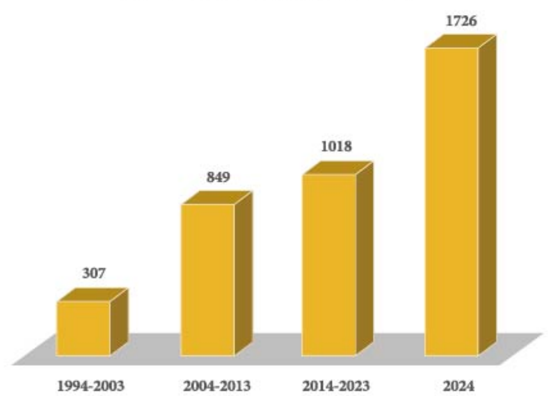
(a) Frequency of disasters (unit: times)



(b) Fatalities (unit: persons)



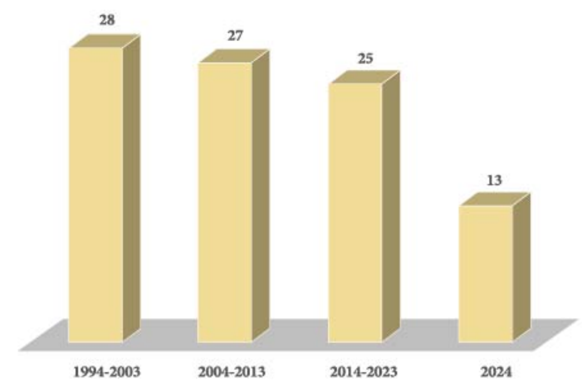
(c) Affected population (unit: ten thousand persons)



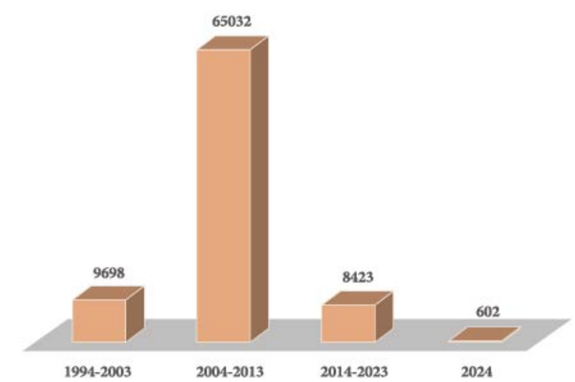
(d) Direct economic loss (unit: USD 0.1 billion)

Figure 4 Global average annual storm disaster losses, 1994-2023 vs. 2024

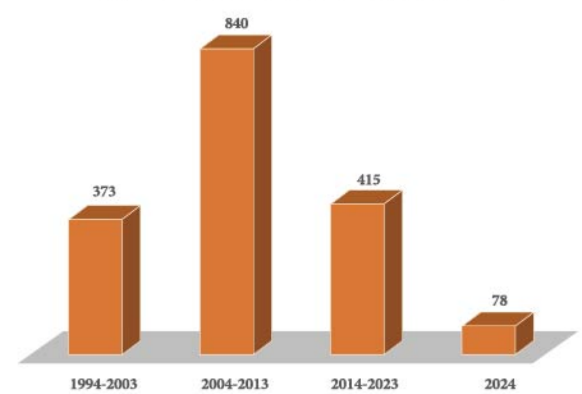
(Note: The direct economic losses from 1994 to 2023 are measured at the price level of 2023, and those of 2024 are measured at the price level of the current year.)



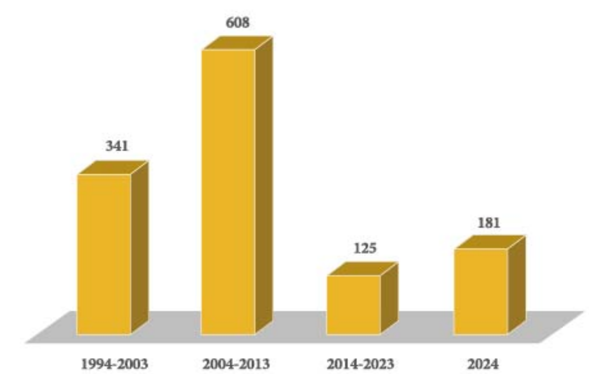
(a) Frequency of disasters (unit: times)



(b) Fatalities (unit: persons)



(c) Affected population (unit: ten thousand persons)



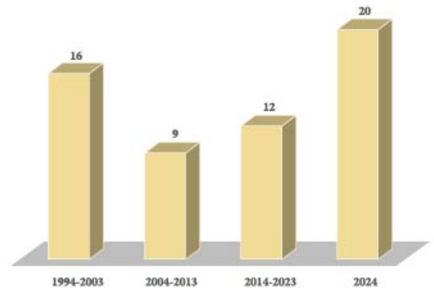
(d) Direct economic loss (unit: USD 0.1 billion)

Figure 5 Global average annual earthquake disaster losses, 1994-2023 vs. 2024

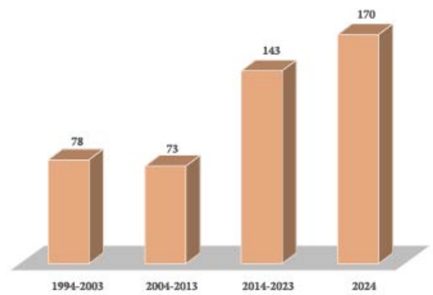
(Note: The direct economic losses from 1994 to 2023 are measured at the price level of 2023, and those of 2024 are measured at the price level of the current year.)

2.5 More frequent wildfires and larger death toll

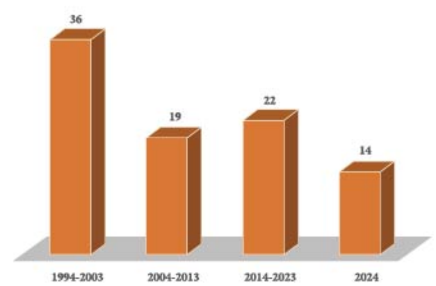
In 2024, there were 20 major wildfires that caused significant losses, higher than the averages in recent years (the annual average over both the past 10 years and the past 30 years has stood at 12). Compared to the average for the last 30 years (1994-2023), global forest fires in 2024 resulted in a 74% increase in fatalities, a 47% decrease in the number of affected population, and a 9% reduction in direct economic losses. Compared to the average for the last 10 years (2014-2023), the fatalities of global forest fires in 2024 rose by 19%, while the affected population decreased by 38%, and direct economic losses dropped by 48% (Figure 6). On 1 February, 2024, a wildfire broke out in the Valparaíso Region of central Chile, ultimately resulting in 135 fatalities. In 2024, multiple regions in the United States were affected by wildfires, with five large-scale wildfire disasters occurring consecutively, impacting over 2,200 people. This series of disasters has led to a significant surge in the frequency of wildfires globally in 2024, accompanied by a marked increase in disaster-related fatalities.



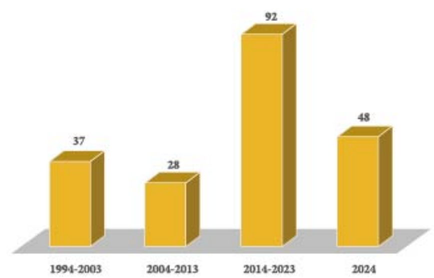
(a) Frequency of disasters (unit: times)



(b) Fatalities (unit: persons)



(c) Affected population (unit: ten thousand persons)



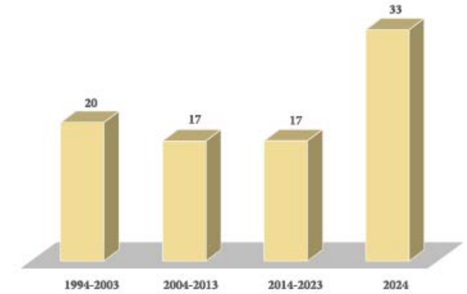
(d) Direct economic loss (unit: USD 0.1 billion)

Figure 6 Global average annual wildfire disaster losses, 1994-2023 vs. 2024

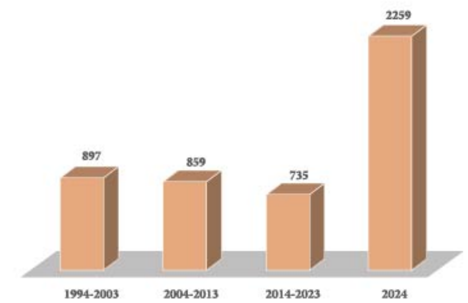
(Note: The direct economic losses from 1994 to 2023 are measured at the price level of 2023, and those of 2024 are measured at the price level of the current year.)

2.6 Increased occurrence of landslide disasters and a rise in fatalities and affected population

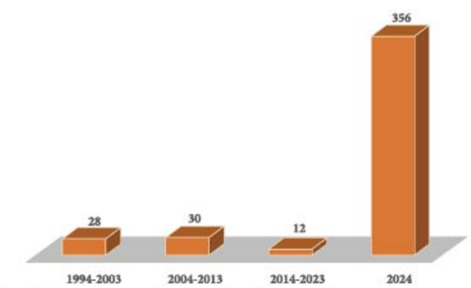
A total of 33 major landslide disasters occurred in 2024, accounting for about 10.6% of the total number of major disasters. Compared with the average for the last 30 years (1994-2023), landslide disasters in 2024 showed an 83% increase in frequency, a 172% rise in fatalities, a 14-fold growth in the affected population, and a 9% increase in direct economic losses. Compared with the average for the last 10 years (2014-2023), landslide frequency in 2024 was 92% higher, fatalities were 208% greater, the number of affected population increased 2900%, and direct economic losses rose by 15% (Figure 7). Among the global landslide disasters in 2024, five caused over 100 fatalities each. Among them, a large-scale landslide occurred in Enga Province, Papua New Guinea, at around 3 a.m. local time on 24 May, resulting in approximately 670 fatalities.



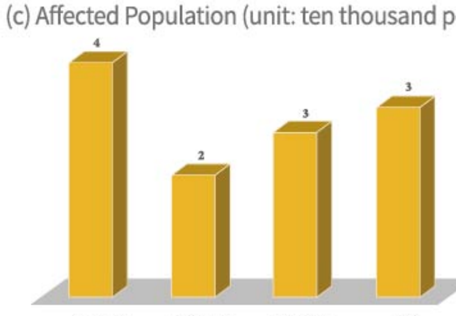
(a) Frequency of disasters (unit: times)



(b) Fatalities (unit: persons)



(c) Affected Population (unit: ten thousand persons)



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

Figure 7 Global average annual landslide disaster losses, 1994-2023 vs. 2024

(Note: The direct economic losses from 1994 to 2023 are measured at the price level of 2023, and those of 2024 are measured at the price level of the current year.)

3

Global patterns of natural disasters in 2024

3.1 Spatial pattern of global natural disasters in 2024

In 2024, the main types of natural disasters occurring globally include meteorological and hydrological disasters such as floods, storms, and droughts, as well as geological disasters such as earthquakes and landslides (Figure 8). Floods were the most frequent natural hazards globally in 2024, with 128 recorded occurrences across 77 countries, primarily in Asia, Africa, and the Americas. Storms followed, affecting 66 countries and regions through 87 events, mainly concentrated in the Americas, Asia, and Africa. Landslides occurred 33 times, affecting a total of 18 countries, mostly in Asia; wildfires struck 20 times across 13 countries, largely in the Americas; earthquakes hit 13 times, impacting 12 countries, mainly in Asia; extreme temperature events affected 17 countries through 11 events, chiefly in Asia; droughts hit 12 countries through 11 events, primarily in Africa; and volcanic eruptions disrupted three countries over (six events, largely concentrated in Southeast Asia).

128 Flood disasters	87 Storm disasters	33 Landslide disasters	20 Wildfire disasters
13 Earthquake disasters	11 Extreme temperature disasters	11 Drought disasters	6 Volcanic disasters

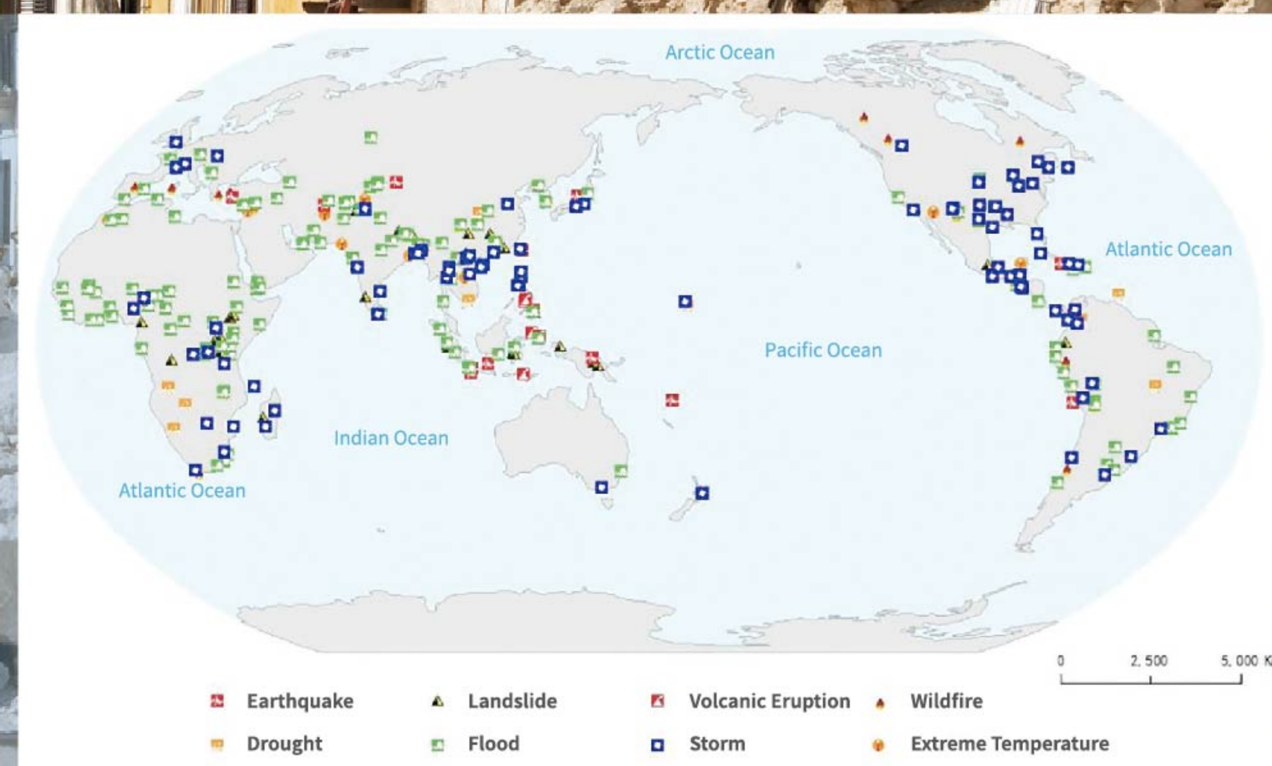
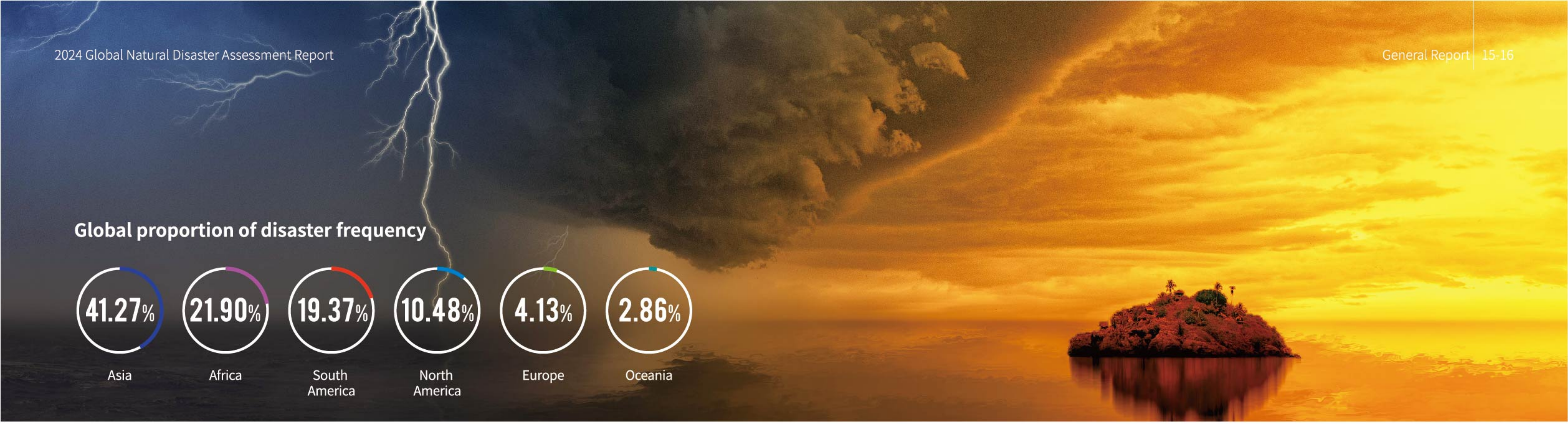


Figure 8 Spatial pattern of global natural disasters, 2024



3.2

Natural disasters by continent in 2024

Figure 9 shows the statistics of the frequency of natural disasters, the number of deaths attributed to disasters, and the direct economic losses in all continents in 2024. Among the 315 natural disaster events counted in the statistics (transcontinental disasters are counted separately), Asia had the highest number of disaster eventswith 130 times, accounting for 41.27%; followed by Africa and South America, with 69 and 61 times respectively (accounting for 21.90% and 19.37%); North America had 33 disaster events (accounting for 10.48%), while Europe and Oceania had similar disaster counts, with 13 and 9 times respectively (accounting for 4.13% and 2.86%).

In terms of deaths caused by disasters, Asia had the highest number, with 9,820 fatalities, accounting for 58.62% of the global total; Africa ranked second, with 3,587 fatalities, accounting for 21.41%. In 2024, 33 disaster events each resulted in over 100 fatalities. These were distributed across Asia (16 events), Africa (10), South America (3), North America (2), Europe (1), and Oceania (1). Among these, three events exceeded 1,000 fatalities each: two in Asia and one in North America. In terms of direct economic losses, North America suffered the largest losses at USD 164.885 billion, accounting for 68.15% of the total economic losses from natural disasters globally. Asia followed with USD 32.202 billion, accounting for 13.31%. The disaster events that caused direct economic losses of more than USD 100 million at a time occurred mostly in North America (26), South America (18), and Asia (15). In addition, 17 such disaster events occurred in other parts of the world (six in Europe, two in Oceania, and nine in Africa). The disaster that caused the largest direct economic loss was Hurricane Helene, which occurred in North America in September, amounting to USD 56 billion.

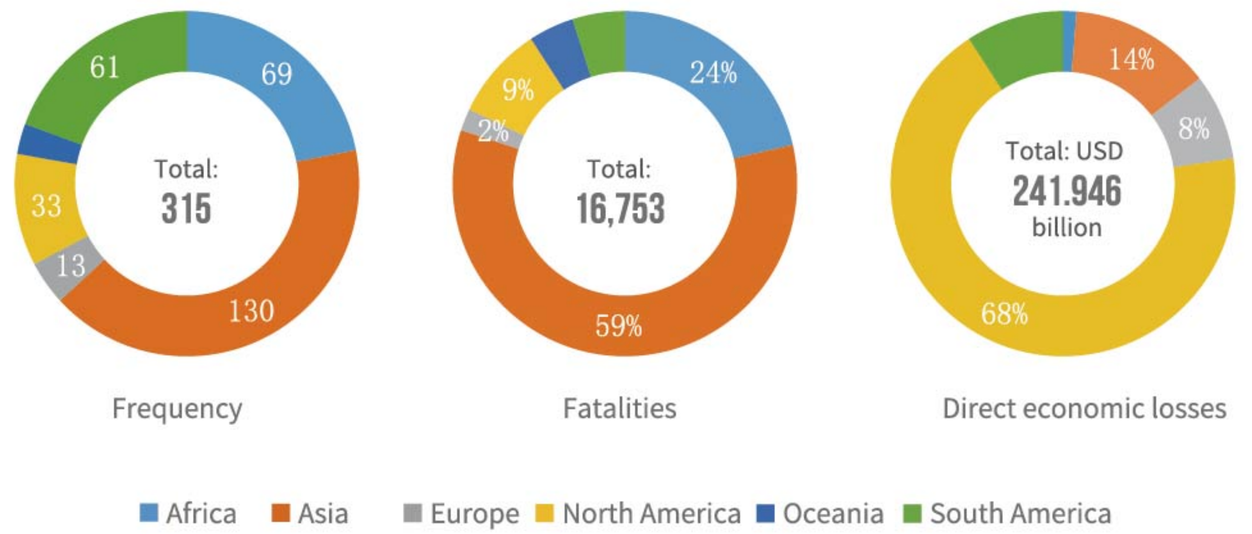


Figure 9 Statistics on the frequency of natural disasters, fatalities and direct economic losses by continent, 2024

(Note: Among the 309 global natural disasters documented in 2024, five were transcontinental hurricanes (one moving from Oceania to Asia, three from Asia to Europe, and one from North America to South America) and one was a transcontinental flood (from Europe to Asia). Since these 6 events were tallied in the statistics for every continent they impacted, the aggregate count reached 315.)

3.3

Natural disasters by country or region in 2024

Figures 10, 11 and 12 show the spatial distribution of the frequency of natural disasters, fatalities, and direct economic losses for each country or region in 2024 respectively. Tables 2 and 3 list 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 10 countries with the highest frequency of disasters were mainly located in North America and Southern and Southeastern Eurasia. The United States experienced the most events (29), followed by China (22) and Indonesia (20). The countries with a higher number of disaster-related deaths are mainly located in Western, Southern, and Southeastern Asia. The top 10 countries all have death tolls exceeding 300, with Afghanistan having the highest at 1,845, followed by India with 1,507. The country with the highest death toll per million people is Papua New Guinea, with 67.18, while the lowest is Kenya, with 7.03. China's death rate per million people is 0.34. The countries with the highest direct economic losses are mainly located in East Asia, Western Europe, and North and South America. The top 10 countries all have losses exceeding USD 2 billion, with the United States having the highest at USD 155.935 billion, followed by Japan and Brazil at USD 16.3 billion and USD 13.61 billion, respectively. In terms of direct economic losses as a percentage of the previous year's GDP, all countries except Vanuatu, the Central African Republic, Malawi, Laos, Zimbabwe, and Niger are below 1%. Among the top 10 countries by economic loss percentage, Vanuatu has the highest direct economic loss ratio at 8.88%, while Brazil has the lowest at 0.63%.

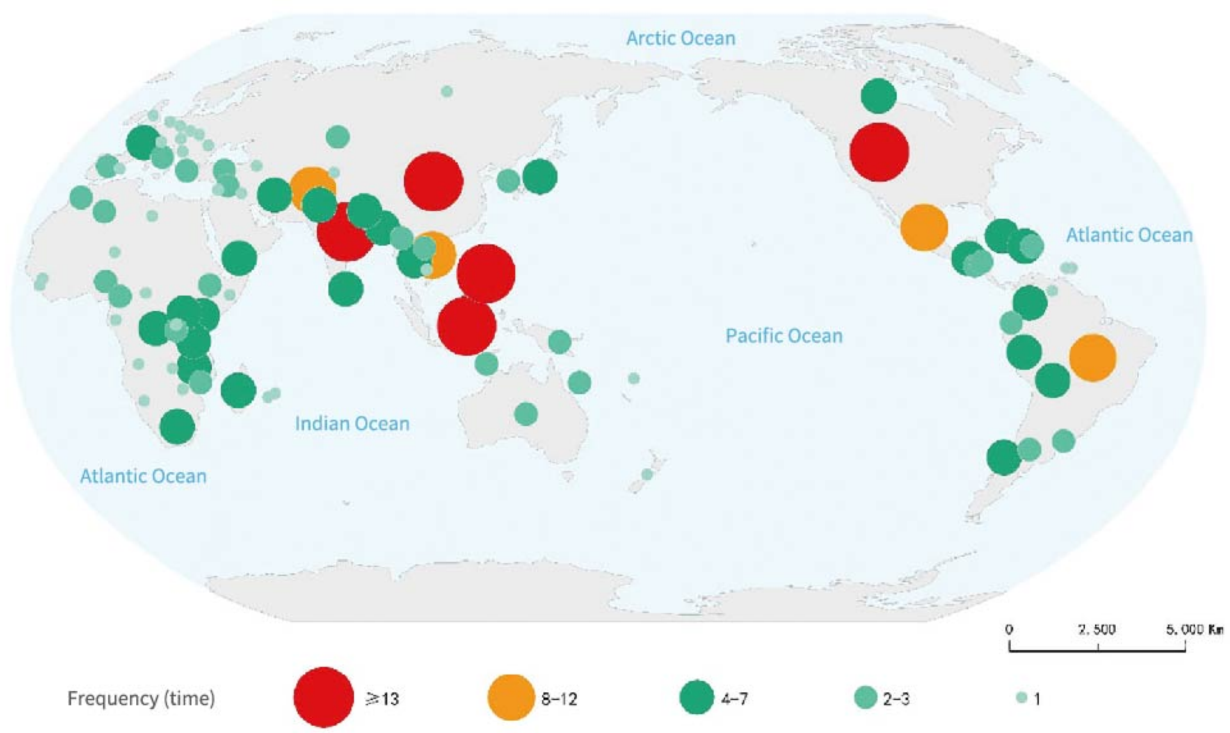


Figure 10 Spatial distribution of disaster frequency by country/region globally in 2024

(Note: Frequency counts for disasters in this section are disaggregated by country/region.)

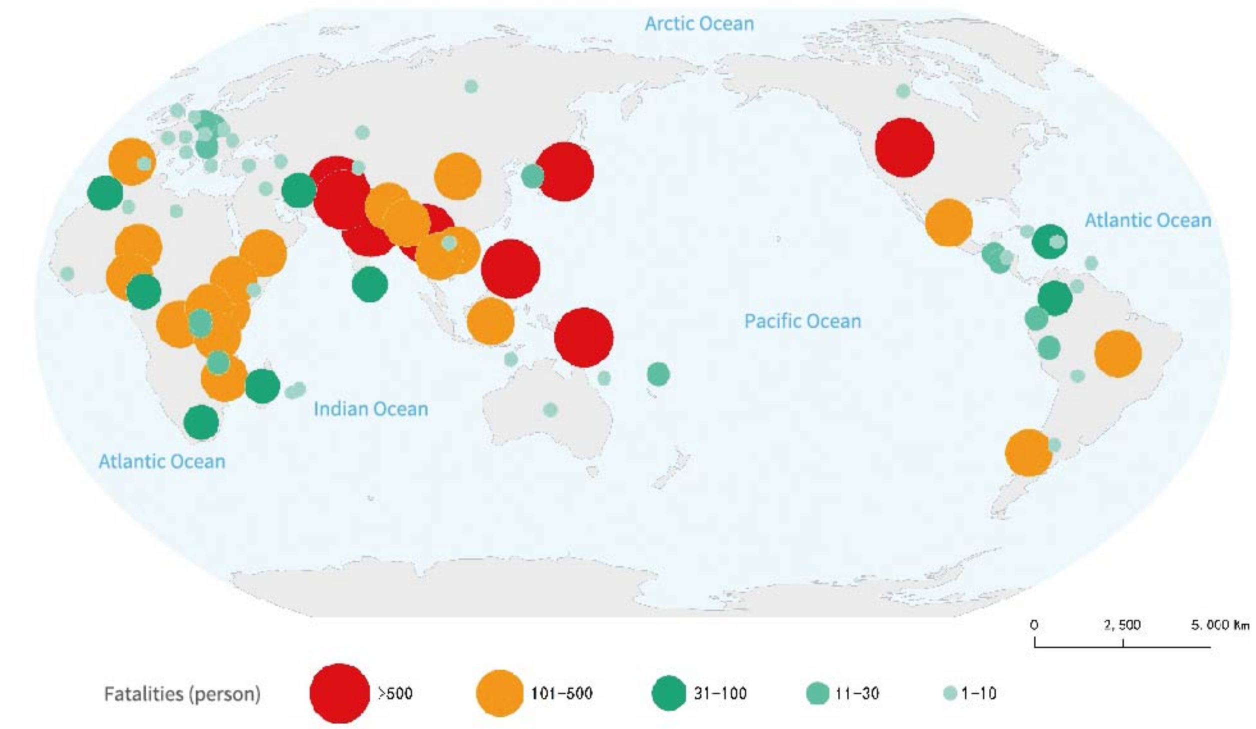


Figure 11 Spatial distribution of disaster fatalities by country/region in 2024

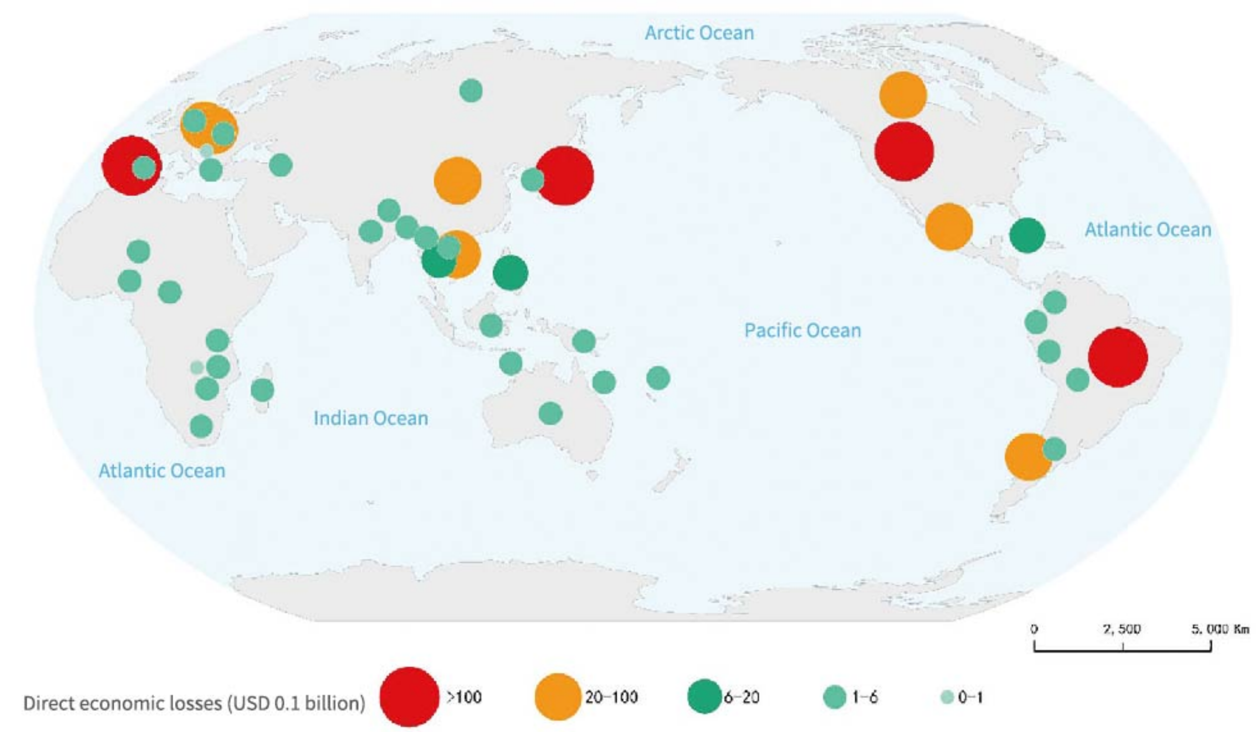


Figure 12 Spatial distribution of disaster direct economic losses by country/region in 2024

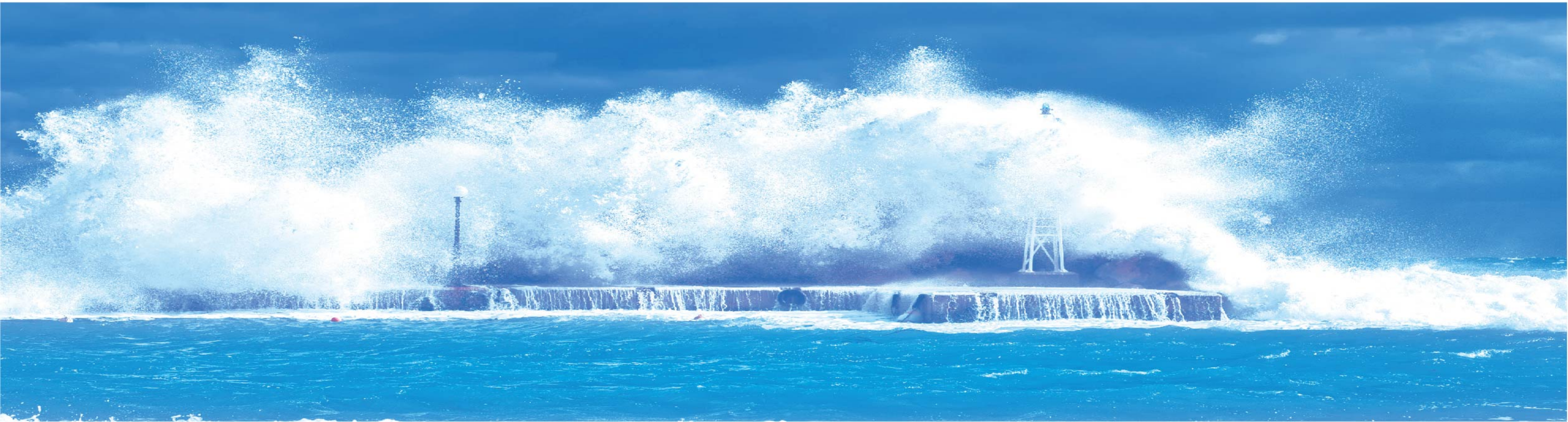
Table 2 Top ten countries (or regions) in terms of disaster frequency and losses globally in 2024

Country (or region)	Frequency (times)	Country (or region)	Deaths (persons)	Country (or region)	Direct economic losses (USD 0.1 billion)
The United States	29	Afghanistan	1845	The United States	1559.35
China	22	India	1507	Japan	163
Indonesia	20	The United States	1464	Brazil	136.1
The Philippines	18	Pakistan	1082	Spain	110.5
India	15	Japan	698	China	100.882
Brazil	11	Papua New Guinea	698	Canada	89.5
Vietnam	10	The Philippines	524	Germany	45
Afghanistan	8	Myanmar	510	Czech Republic	30
Mexico	8	China	476	Mexico	25.9
Canada	7	Niger	396	Chile	20.8

Table 3 Top ten countries (or regions) in terms of disaster loss rates globally in 2024

Country (or region)	Deaths per million population	Country (or region)	Percentage of direct economic losses (%)
Papua New Guinea	67.18	Vanuatu	8.88
Afghanistan	44.51	Central African Republic	5.67
Vanuatu	43.69	Malawi	3.15
Saint Vincent and the Grenadines	29.61	Laos	1.91
Niger	15.14	Zimbabwe	1.42
Nepal	12.76	Niger	1.34
Myanmar	9.42	Czech Republic	0.87
Yemen	8.68	Nepal	0.83
Bosnia and Herzegovina	8.48	Spain	0.68
Kenya	7.03	Brazil	0.63

(Note: The number of deaths per million in the table refers to the proportion of disaster-related deaths in 2024 in the total population of the affected countries/regions in 2024 (expressed as deaths per million). The percentage of direct economic losses refers to the total direct disaster-related economic losses in 2024 as a share of GDP in 2023 The population and GDP (in current USD) data for 2024 are sourced from the World Bank (https://data.worldbank.org/).)



3.4 Top ten natural disasters in terms of global fatalities and direct economic losses in 2024

Table 4 and Figure 13 respectively show the world's top 10 disaster events with the highest death toll in 2024 and their spatial distribution. It is evident that those events with higher death tolls predominantly occurred in economically underdeveloped developing countries/regions, primarily characterized by meteorological and hydrological disasters such as extreme heat, storms and floods. This is related to the low level of economic development, weak infrastructure resilience, insufficient disaster monitoring and early warning systems, and lower levels of emergency rescue and medical services in these countries/regions.

Table 4 Top 10 natural disasters worldwide by fatalities in 2024

Ranking	Time	Affected countries/regions	Type of disaster	Fatalities (persons)	Mortality rate (per million population)
1	June 1-June 20	Saudi Arabia	Extreme heat	1301	35
2	February-March	Afghanistan	Extreme cold	1197	28
3	April 18-October 31	The United States	Extreme heat	1006	3
4	September 1-September 13	China, Myanmar, Philippines, Laos, Thailand, Vietnam	Storm	892	0.5
5	March-June	Bangladesh	Extreme heat	733	1
6	May 23-May 24	Papua New Guinea	Landslide	670	67
7	August 1-September 30	Chad	Flood	576	32
8	June 20-June 25	Pakistan	Extreme heat	568	2
9	January 1	Japan	Earthquake	551	4
10	July 9-July 15	India	Flood	493	1

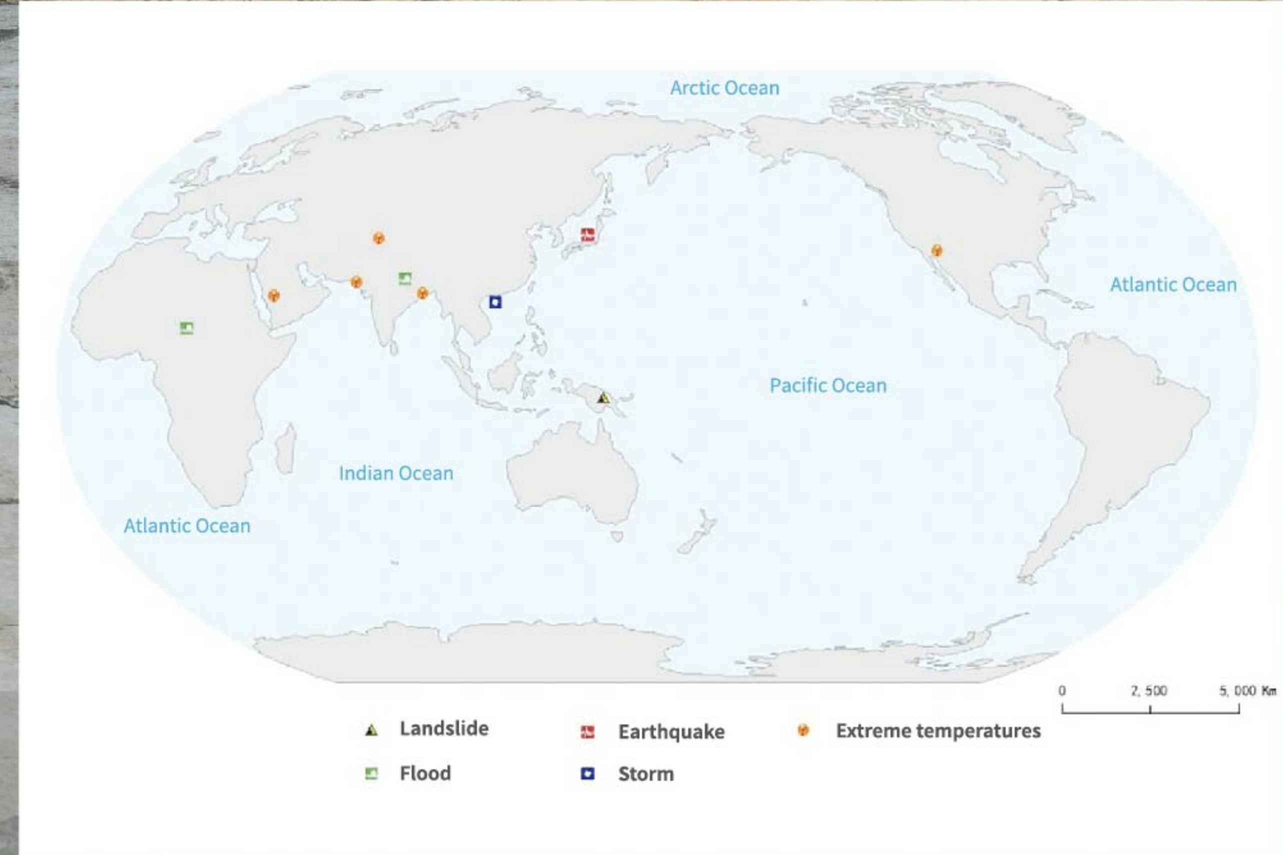


Figure 13 Spatial distribution of the world's top 10 natural disasters in fatalities in 2024

Table 5 and Figure 14 list the world's top 10 disaster events in 2024 with the highest direct economic losses and their spatial distribution. It can be seen that those disaster events with higher direct economic losses are mostly concentrated in economically developed coastal countries, with storms and floods being the main types of disasters.

Table 5 Top 10 natural disasters worldwide in direct economic losses in 2024

Ranking	Time	Affected countries/regions	Type of disaster	Direct economic losses (USD 0.1 billion)
1	September 27-September 28	Cuba	Storm	560
2	October 9-October 10	Mexico	Storm	380
3	January 1-January 1	Japan	Earthquake	150
4	October 27-November 4	Spain	Flood	110
5	July 12	Canada	Storm	86.3
6	May-May 13	Argentina	Flood	70
7	May 6-May 8	The United States	Storm	66
8	January 1-December 31	Brazil	Drought	60.5
9	March 12-March 16	The United States	Storm	59
10	August 8-August 10	Canada	Storm	55

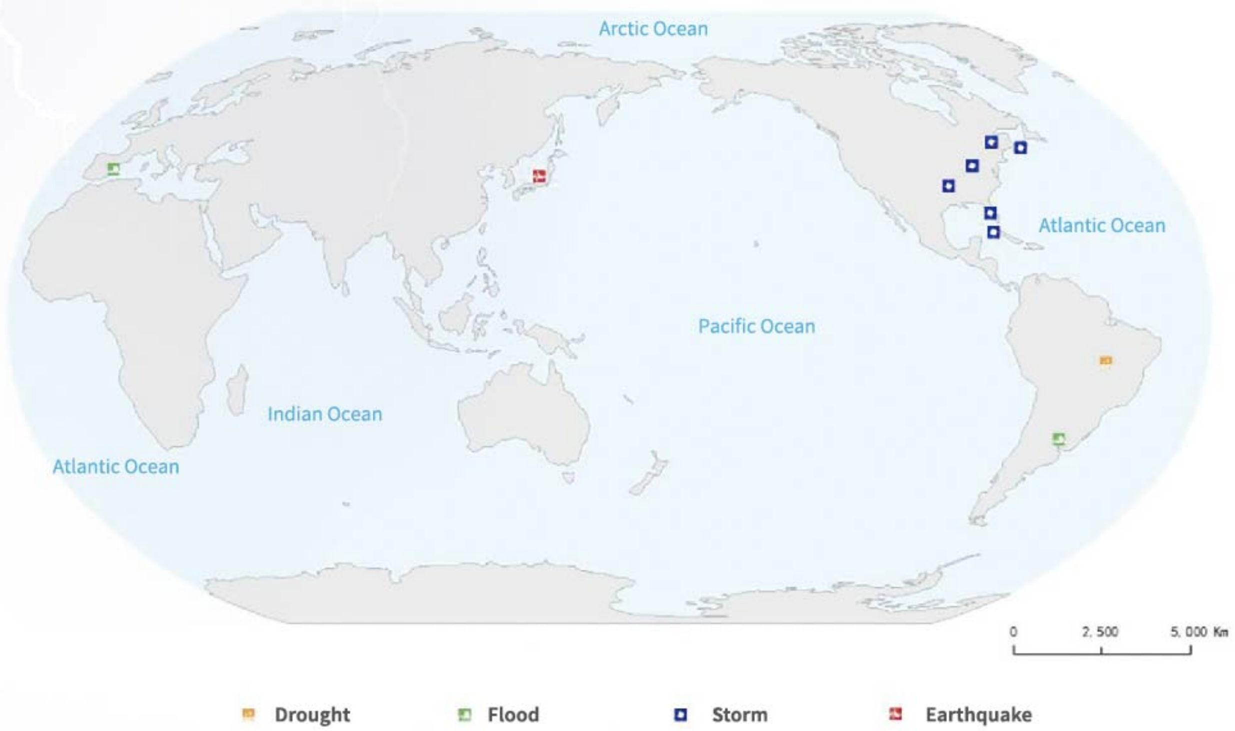


Figure 14 Spatial distribution of top 10 natural disasters worldwide in direct economic losses in 2024

4

Comparison of natural disasters between China and the rest of the world in 2024

4.1 Comparison of natural disaster related fatalities between China and the rest of the world in 2024

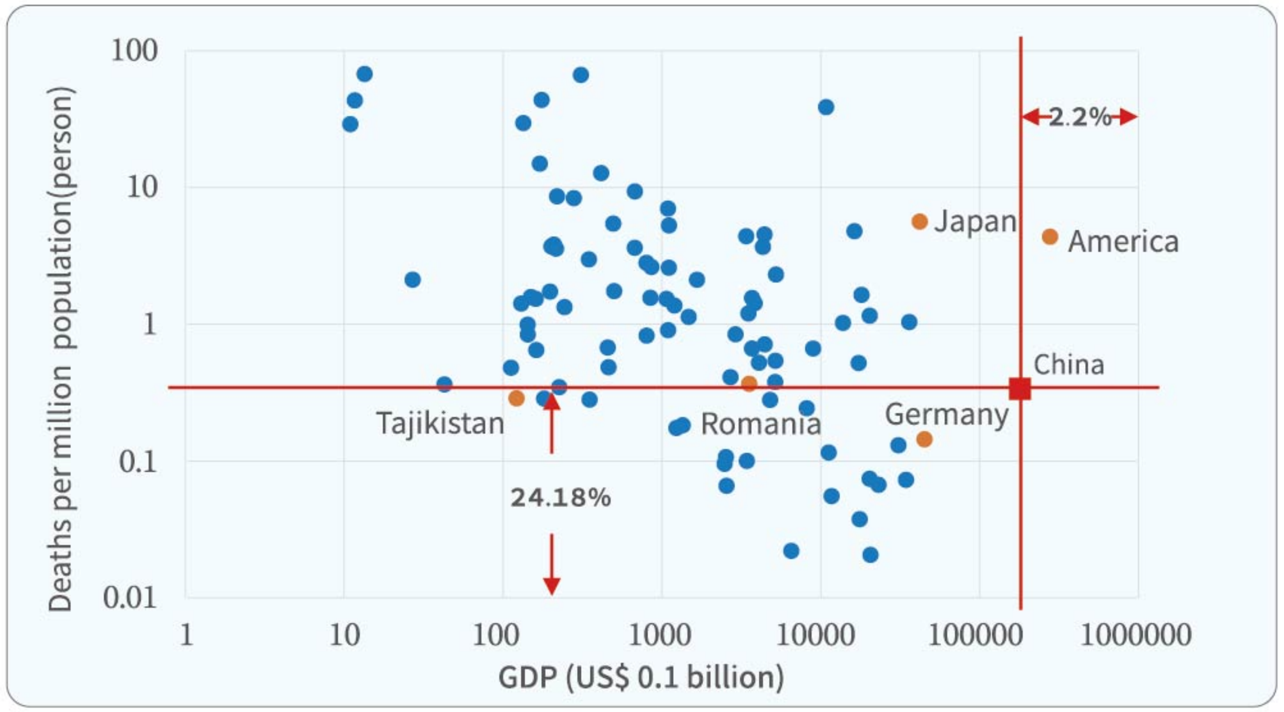
Figure 15 shows the number of deaths per million population due to natural disasters in major countries and regions around the world in 2024.

In 2024, China's disaster-related mortality rate per million population was 0.34. Ranked by this metric from lowest to highest, China placed in the top 24.18% among the 91 countries/regions included in the statistics. Countries with a disaster-related mortality rate per million population similar to that of China included Nicaragua (0.29), Guinea (0.35), and Romania (0.36).

In terms of mortality rate per million population in relation to the level of economic development, China's mortality rate per million population was basically consistent with the level of its economic development in 2024, and the count was relatively low in the global range. Compared to countries with a similar level of economic aggregates as China, the disaster-related mortality rate per million population was higher in the United States (4.37) and Japan (5.61) but lower in Germany (0.14). For countries with similar per capita GDP, Russia (0.02) and Türkiye (0.12) report lower rates, while Mexico (1.66) reports a higher rate than China.

Disaster-related mortality per million population by country

0.34	4.37	5.61	0.14
China	United States	Japan	Germany



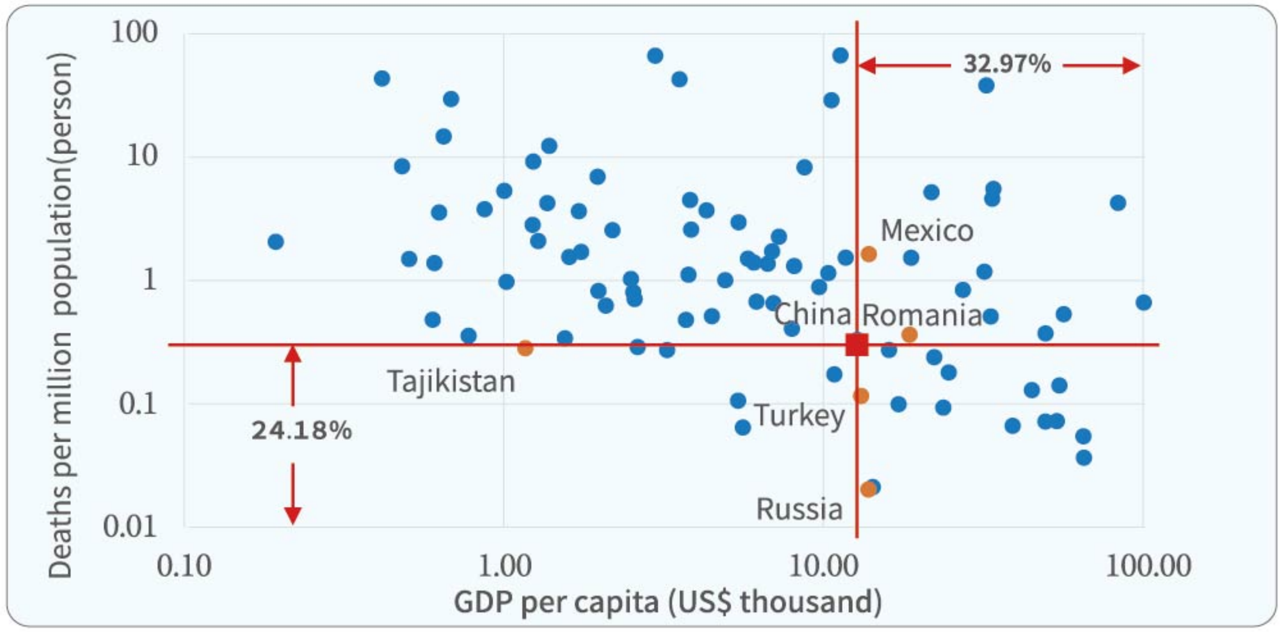


Figure 15 Comparison of natural disaster fatalities between China and the rest of the world in 2024

Note:
Horizontal comparison between China and the other 90 countries/regions in the world.
China ranked in the top 24.18% in terms of mortality rate per million population, which was in the lower level;
China's total GDP ranked second; its per capita GDP ranked in the top 32.97%, which was in the upper-middle level;
The mortality rate per million population in China was basically consistent with the level of its economic development.
(The disaster-related mortality rate per million people shown in the figure was calculated by dividing the 2024 disaster-related death toll from 91 countries/regions by their respective 2024 population in millions. The population data come from the World Bank (https://data.worldbank.org/), and the GDP data are from the GDP figures (in current USD) in 2024 released by the World Bank).

4.2

Comparison of direct economic losses from natural disasters between China and the rest of the world in 2024

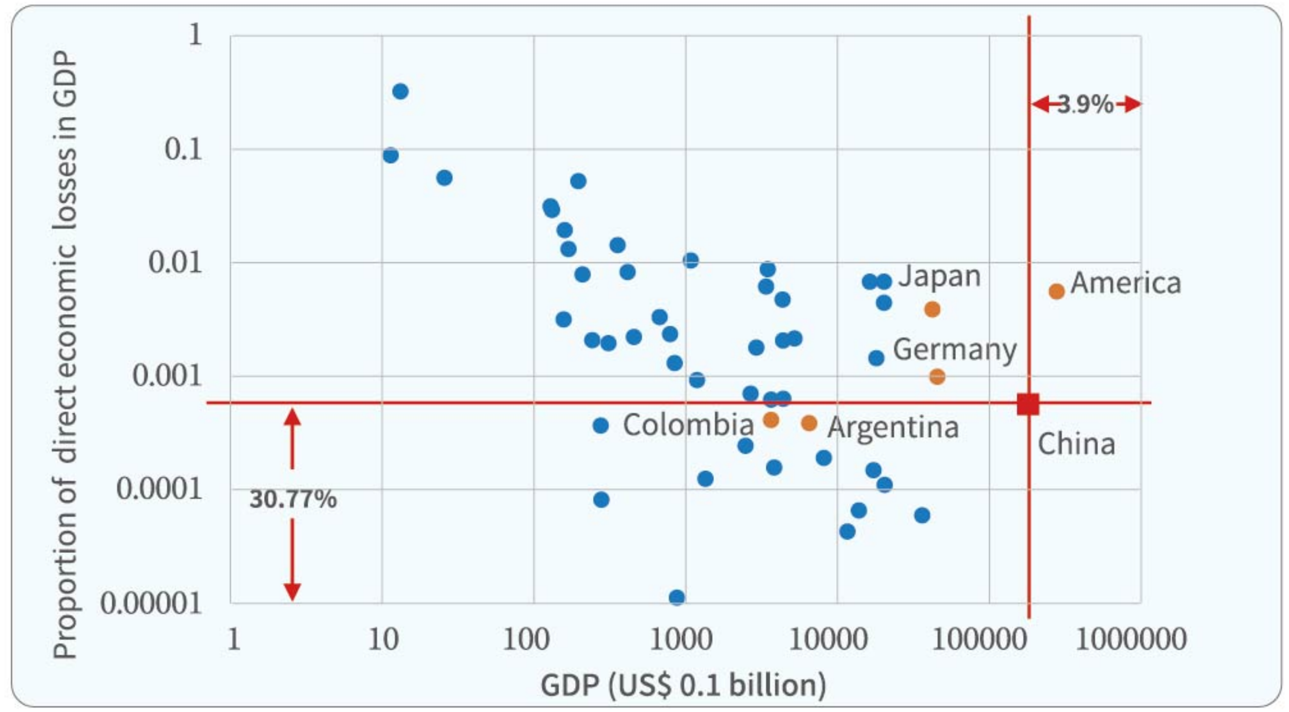
Figure 17 shows the direct economic losses as a percentage of GDP for major countries and regions worldwide in 2024.

The direct economic losses caused by natural disasters in China accounted for 0.057% of its GDP. In terms of the proportion of direct economic losses in GDP, China ranked in the top 30.77% among the 52 countries/regions surveyed, from low to high. Countries with direct economic losses as a percentage of GDP similar to China included Argentina (0.039%), Bosnia and Herzegovina (0.036%), and Colombia (0.041%).

In terms of the relationship between the proportion of direct economic losses in GDP and the level of economic development in 2024, China's direct natural disaster economic losses were roughly consistent with the level of its economic development, and China ranked in the middle-lower 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 (0.56%) and Germany (0.1%) had a higher share of direct economic losses in GDP than China. Compared to countries with a per capita GDP similar to that of China, the direct economic losses as a percentage of GDP in Russia (0.01%) and Argentina (0.039%) were lower than those in China, while Mexico (0.14%) and Brazil (0.68%) had a higher share.

Direct economic losses from disasters as a percentage of GDP by country

0.057%	0.56%	0.1%	0.01%
China	United States	Germany	Russia



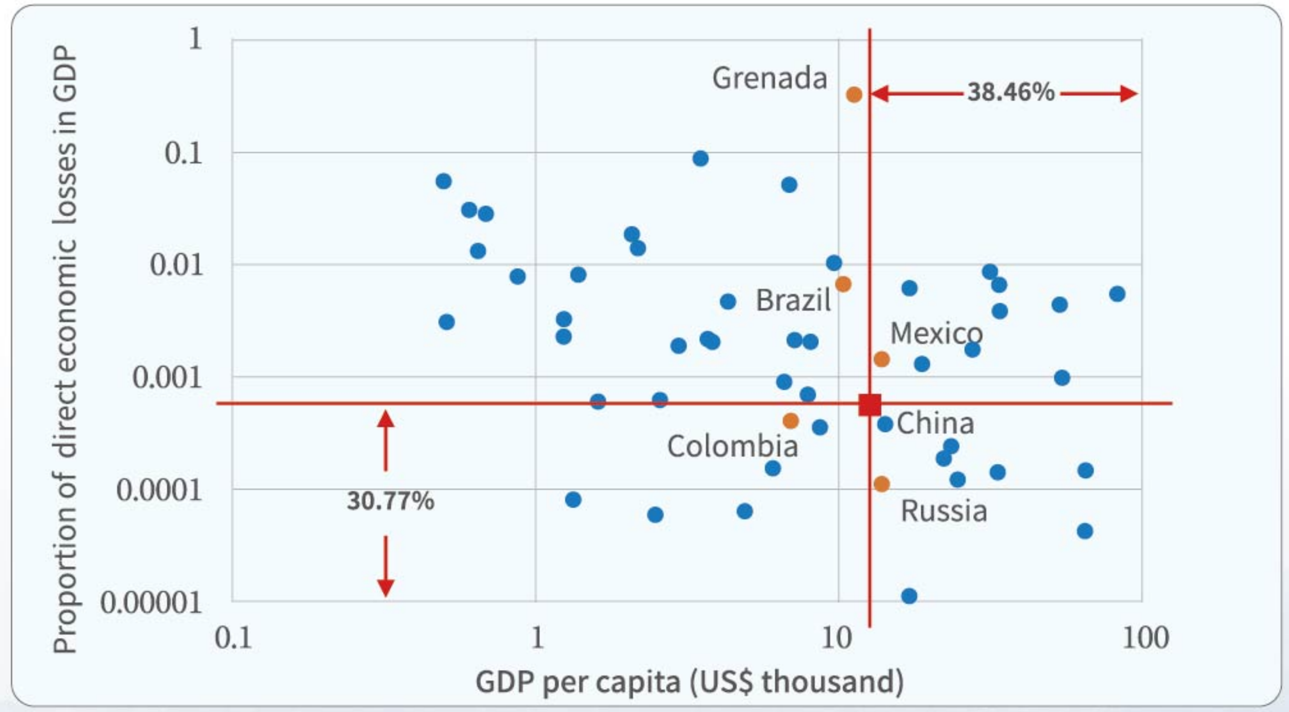


Figure 16 Comparison of direct economic losses from natural disasters as a share of GDP between China and the rest of the world in 2024

Note:
Horizontal comparison between China and the other 51 countries/regions in the world.
China ranked in the top 30.77% in terms of the annual average direct economic losses as a percentage of GDP in ascending order, which was at the middle-lower level.
China's total GDP ranked the second; its per capita GDP ranked in the top 38.46%, which was at the middle level;
China's proportion of direct economic losses in GDP was basically consistent with the level of its economic development.
(The ratio of direct economic losses over GDP shown in the figure was calculated by dividing the direct economic losses from natural disasters in 2024 by the total GDP of the same year across 52 countries/regions. The population data, GDP (in current USD) and per capita GDP (in current USD) all come from the World Bank (https://data.worldbank.org/).)

02

Special Report 1[1]

Natural Disasters in China in 2024

1. Overview of natural disasters
2. Temporal and spatial characteristics of natural disasters
3. Trend analysis of disaster indicators

[1] The original report provided by: National Disaster Reduction Center of China, Ministry of Emergency Management.

1

Overview of natural disasters

In 2024, China experienced a complex and severe series of natural disasters, mainly including floods, geological hazards, hailstorms, typhoons, as well as low-temperature freezing and snow events. Droughts, earthquakes, forest and grassland fires, and sandstorms also occurred to varying extents. Affected by extreme weather events, the central and eastern regions experienced widespread low temperatures and snow disasters, while the southwestern region faced consecutive droughts during winter and spring. During the flood season, both northern and southern China experienced multiple rounds of heavy rainfall, which were characterized by frequent rainstorms, vast spatial extent, and exceptional severity. Compounded by the landfall of Typhoon Gaemi, these conditions led to severe flooding and geological disasters. Besides, drought conditions alternated between the north and south, marked by rapid transitions between drought and flooding. From September to November, autumn typhoons such as Yagi and Trami had a significant impact on southern and eastern China. Throughout the year, various natural disasters affected over 94.13 million people in China, resulting in 856 deaths and missing persons, and the emergency relocation of 3.645 million people. 64,000 houses collapsed, and another 832,000 houses were damaged. The area of crops affected was 10.089 million hectares. Direct economic losses amounted to CNY 401.11 billion. Compared to the average of the past 10 years, the number of affected people, the number of deaths and missing persons due to disasters, and the number of collapsed houses decreased by 36.8%, 12.1%, and 69.5%, respectively, while direct economic losses increased by 12.1%. In 2024, compared to the previous year, China experienced a 1.4% reduction in the number of people affected by natural disasters and a significant 69.2% decrease in the number of collapsed houses. However, the number of deaths and missing persons rose by 23.9%, and direct economic losses increased by 16.2%.

over **94.13** million
Affected population

856
Deaths and missing persons

3.645 million
Emergency relocation

CNY **401.11** billion
Direct economic losses

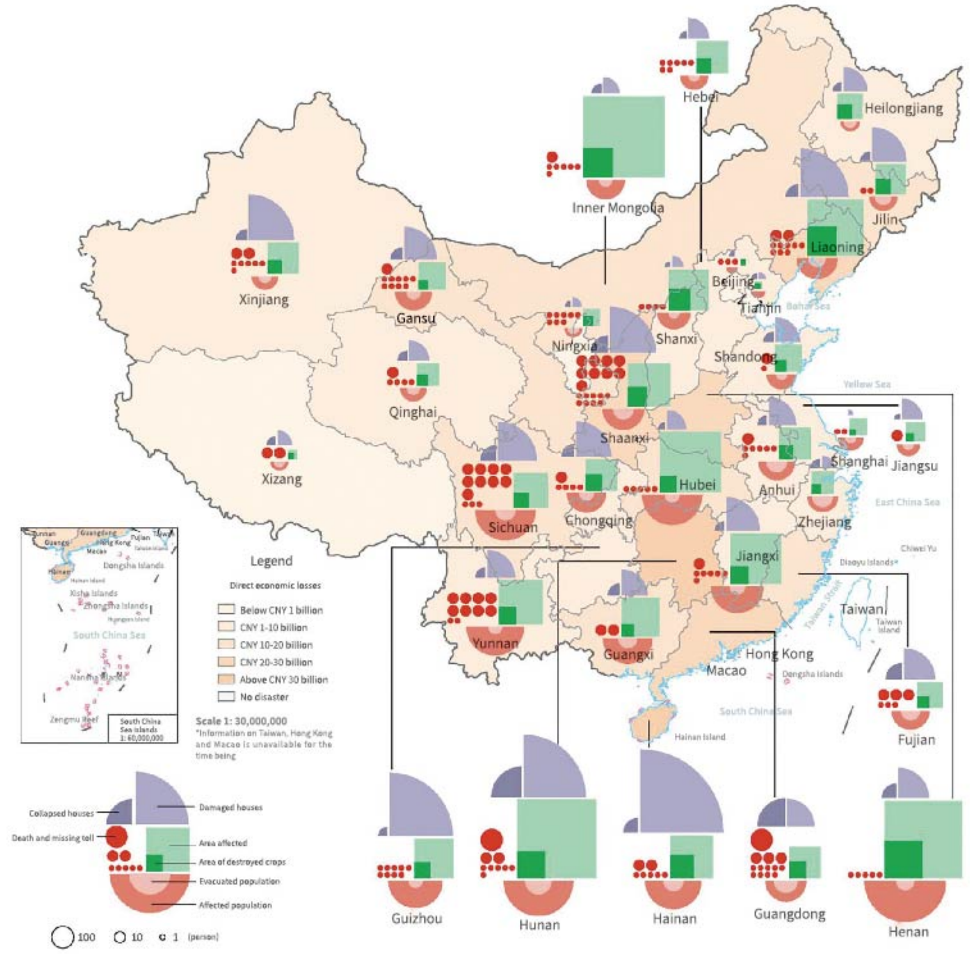


Figure 1 Spatial distribution of natural disasters in China in 2024

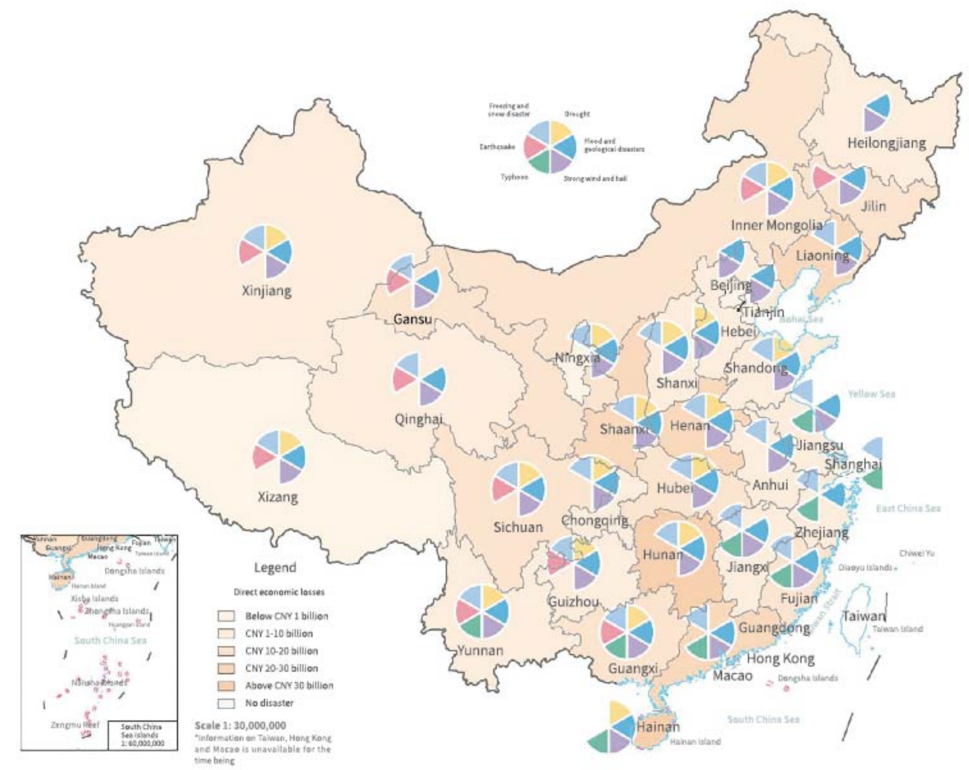


Figure 2 Spatial distribution of direct economic losses in China by hazard type in 2024

1.1 Affected population by hazard type

In 2023, with regard to the population affected by natural disasters in China, floods accounted for the highest proportion (56.6%), followed by typhoons (12.3%), droughts (12.2%), low-temperature freezing and snow disasters (9.6%), and wind and hail disasters (8.5%). Other categories, such as earthquakes, geological hazards and sandstorms, accounted for a relatively low proportion.

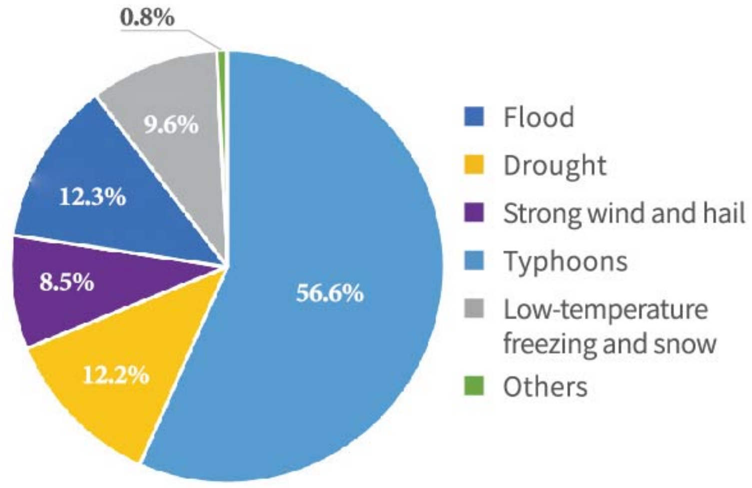


Figure 3 Pie chart of the affected population by hazard type in 2024

1.2 Death and missing toll by hazard type

In 2024, floods were the leading cause of disaster-related death and missing toll in China, accounting for 50.9% of the total. Geological disasters followed at 31.9%, with wind and hail disasters (10.3%), low-temperature freezing and snow disasters (2.8%), and typhoon disasters (2.1%) constituting smaller shares. Other disasters like forest and grassland fires, and earthquakes, accounted for minimal proportions.

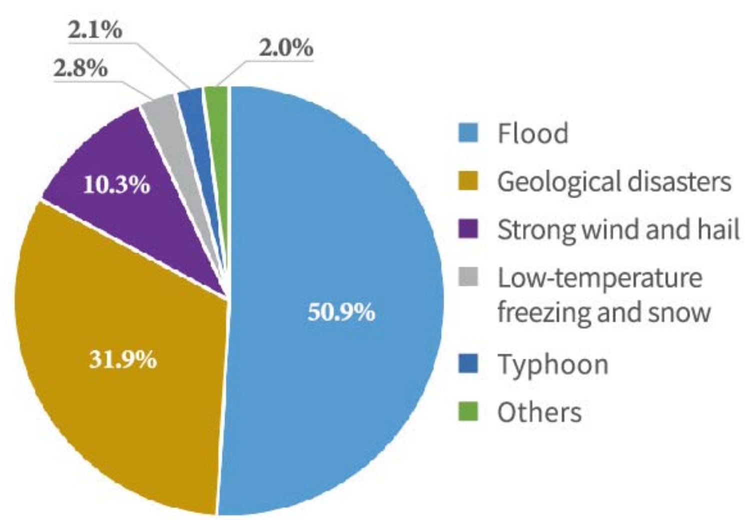


Figure 4 Pie chart of death and missing toll by hazard type in China, 2024

Drowning, geological disasters, the collapse of houses or structures, and lightning strikes are the main causes of deaths and missing persons. Specifically, drowning (primarily resulting from flash floods and river floods) was the single largest cause, responsible for 44.7% of fatalities. Deaths and missing persons from secondary geological disasters (triggered by landslides and mudslides, and floods) accounted for 38.6% of the total, while those caused by the collapse of houses or structures accounted for 5.0%. Lightning strikes caused 4.8% of fatalities, while forest and grassland fires accounted for 1.5%. Other causes (earthquake, falling object, rescue operation, etc.) made up the remaining 2.6%.

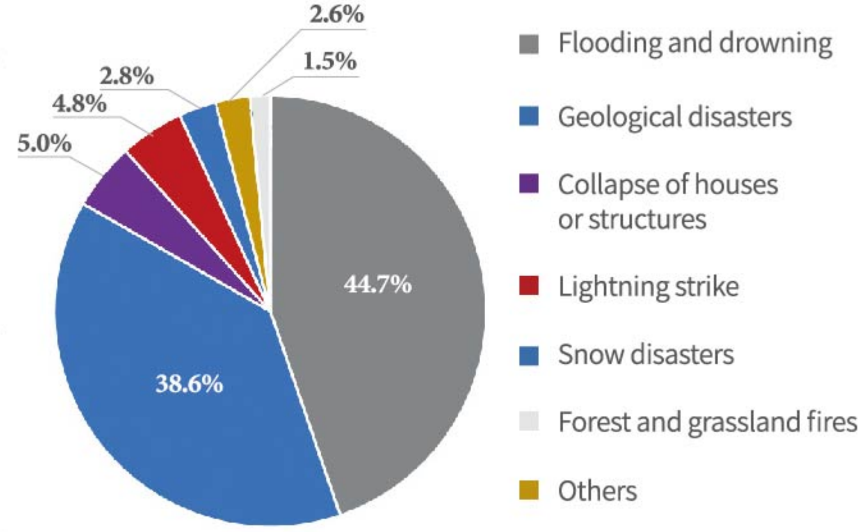


Figure 5 Pie chart of causes of death and missing toll in 2024

1.3 Direct economic losses by hazard type

Regarding direct economic losses in 2024, floods represented the largest share at 64.8%. Typhoons followed at 21.3%, with low-temperature freezing and snow disasters (6.4%), wind and hail disasters (3.6%), and drought disasters (2.1%) comprising the subsequent significant categories. Losses from earthquakes, geological disasters, and sandstorms were comparatively minor.

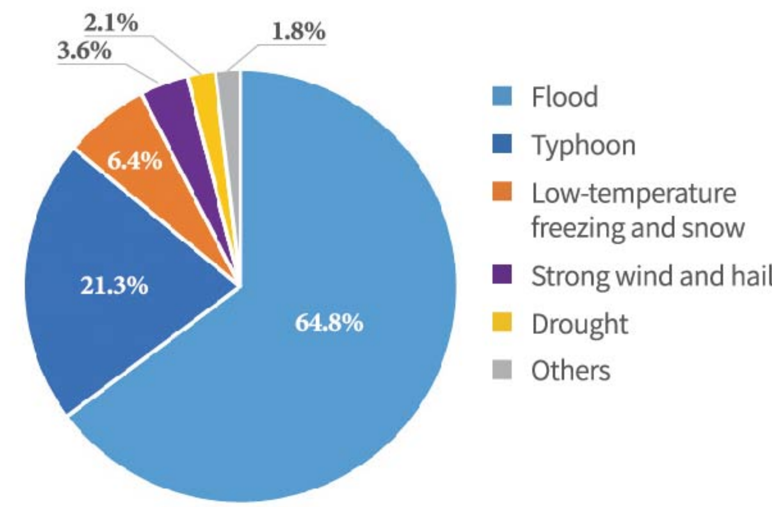


Figure 6 Pie chart of direct disaster economic losses by hazard type in 2024

1.4

Deaths and missing tolls by province

In 2024, Guangdong, Hunan, Shaanxi, Sichuan, and Yunnan each recorded over 80 disaster-related deaths and missing persons, ranking among the top five in China. Guangdong and Hunan suffered a death and missing toll of more than 100 people each. Compared to the average from 2004 to 2023, the number of deaths and missing tolls in 2024 showed positive growth in Guangdong, Hunan, Shaanxi, Hainan, Liaoning, Ningxia, and Shanghai, while the remaining provinces showed negative growth.

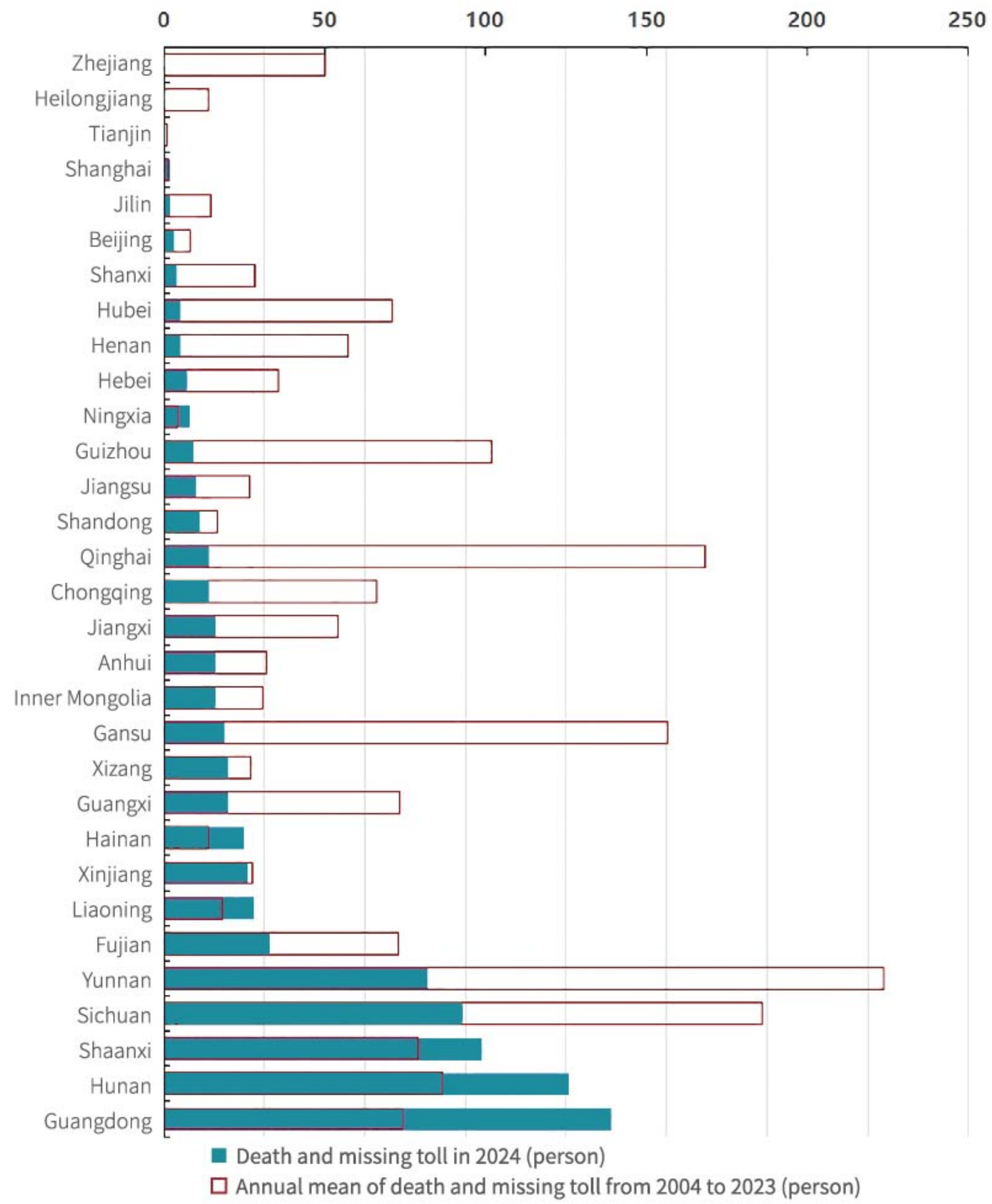


Figure 7 Statistics of deaths and missing tolls by province in 2024

(Note: The statistics of 2008 are not included in the average death and missing toll in Sichuan Province from 2004 to 2023.)

1.5

Direct economic losses by province

In 2024, the direct economic losses in Hunan and Hainan due to disasters exceeded CNY 30 billion, while those in Liaoning and Guangdong exceeded CNY 20 billion (The data of each province were based on 2004 and converted according to the GDP index, the same below). Compared with the average from 2004 to 2023, the direct economic losses due to disasters in 2024 showed positive growth in Hunan, Hainan, Liaoning, Guangdong, Henan, Shaanxi, Fujian, Jilin, Guangxi, and Shanghai, while the remaining provinces showed negative growth.

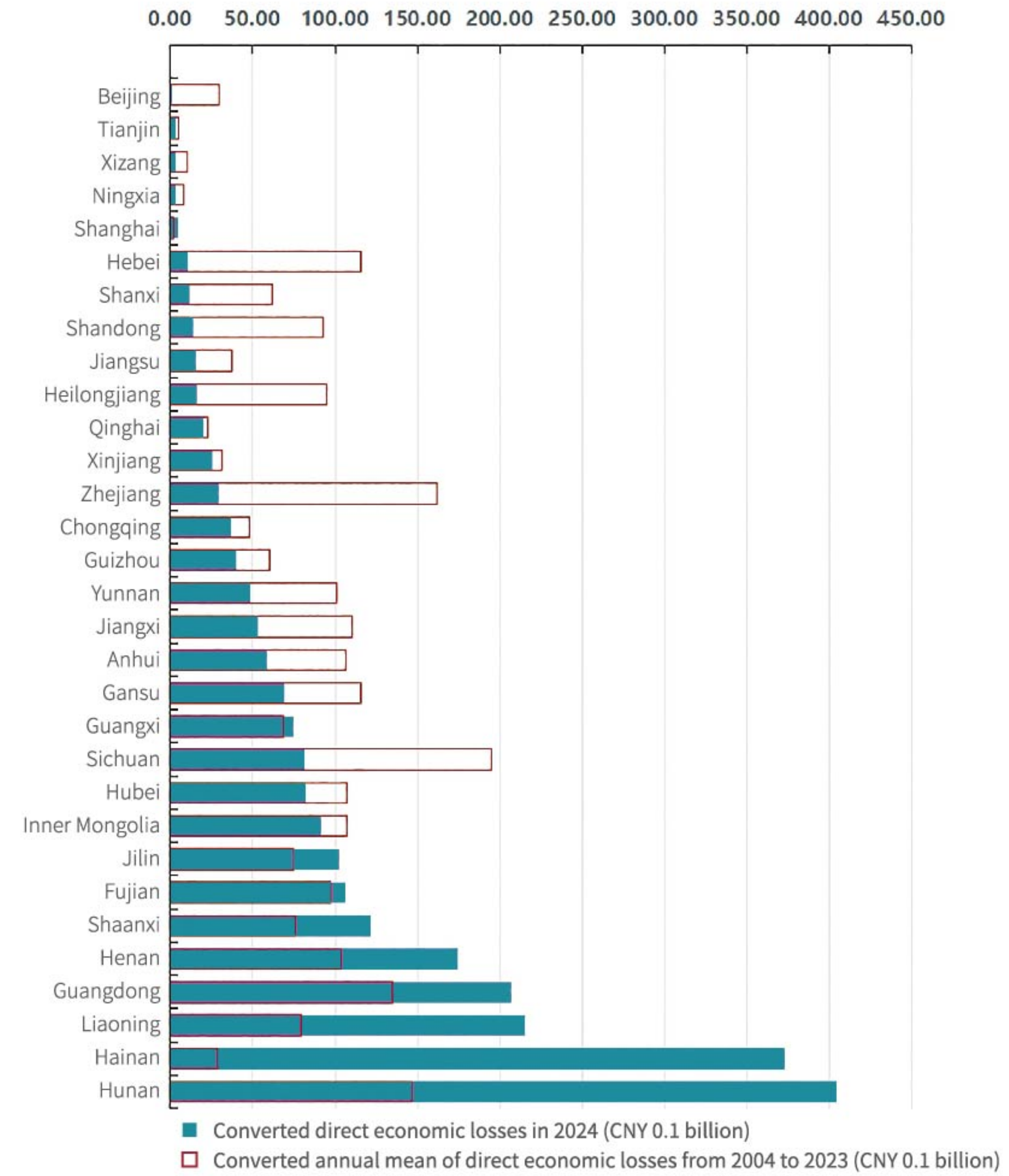


Figure 8 Statistics of direct economic losses from disasters by province in 2024

(Note: Annual data in each province were converted based on comparable prices in 2004 according to the GDP indices. The statistics of 2008 are not included in the average value of the converted direct economic losses in Sichuan Province from 2004 to 2023.)

Table 1 Top ten natural disaster events in China, 2024

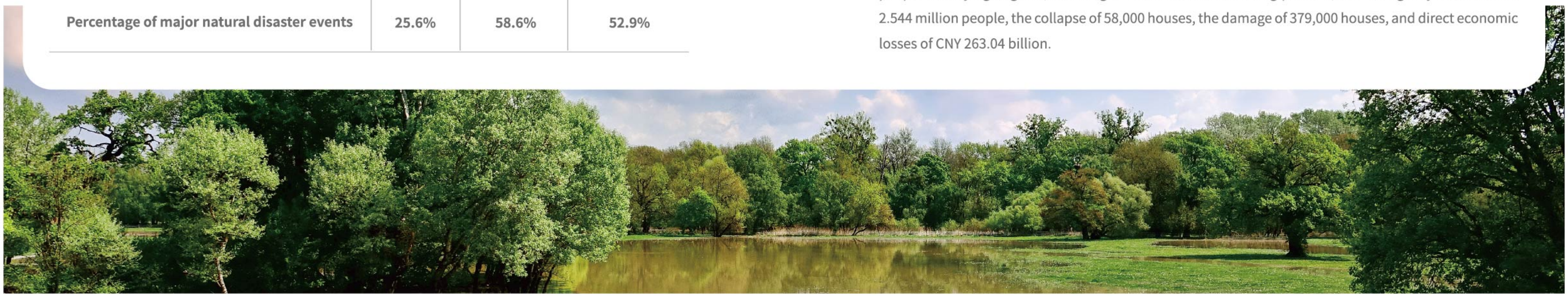
Natural disaster event	Affected population (10,000 persons)	Death and missing tolls (persons)	Direct economic losses (CNY 0.1 billion)
January 22: Landslide in Zhenxiong County, Yunnan Province	0.13	44	1.5
February: Low-temperature, freezing rain, and snow disasters across central and eastern China	630.7	12	223.8
Mid and late April to early May: Severe rainstorms, floods, and geological disasters in Guangdong Province	68.1	74	55.4
Mid-June: Severe rainstorms, floods, and geological disasters in South China	280	91	321.3
Mid and late June to early July: Severe rainstorms, floods, and geological disasters in Hunan Province	388	20	229.9
Mid and late July: Severe rainstorms and floods in Shaanxi Province	56.7	95	164.1
July 20: Mountain flood and mudslide in Hanyuan County, Sichuan Province	6.2	41	10
Late July: Severe rainstorms, floods, and geological disasters in Hunan Province	149.9	94	241.3
Late August: Severe rainstorms and floods in Liaoning Province	92.4	27	154.7
Early September: Disasters caused by Typhoon Yagi	741.5	4	720.3
Total losses of major natural disaster events	**2413.6**	**502**	**2122.3**
National annual total losses	**9413**	**856**	**4011.14**
Percentage of major natural disaster events	**25.6%**	**58.6%**	**52.9%**

2

Temporal and spatial characteristics of natural disasters

2.1 Overall excessive precipitation in China with prominent localized extremes, triggering frequent floods and geological disasters

In 2024, China's average precipitation was 697.7 millimeters, which is 9% more than the normal level. In South China, the precipitation during the pre-flood season was 40% more than the normal level, while the Meiyu rainfall in the middle and lower reaches of the Yangtze River was 51% more than normal. North China experienced rapid drought-flood transition during the late July to early August critical period, with precipitation shifting from a 30% deficit to a 70% surplus. The precipitation in the Songliao River basin was 50% more than the normal level. Rainfall events characterized by extreme high intensity, long duration, and concentrated impact zones affected many areas. Several areas broke historical rainfall records, leading to fluvial floods, flash floods, urban waterlogging, as well as landslides and mudslides, causing significant casualties and economic losses. In mid and late July, heavy rain and flooding in Shaanxi Province caused 95 deaths and missing persons in the cities of Shangluo and Baoji, with direct economic losses of CNY 16.41 billion. In late July, heavy rain and geological disasters in Hunan Province caused 94 deaths and missing persons in cities of Chenzhou and Hengyang, with direct economic losses of CNY 24.13 billion. In 2024, floods and geological disasters affected 53.449 million people to varying degrees, resulting in 709 deaths and missing persons, the emergency relocation of 2.544 million people, the collapse of 58,000 houses, the damage of 379,000 houses, and direct economic losses of CNY 263.04 billion.



2.2 Above-average typhoon formation and landfall, with severe impacts from autumn typhoons in South and East China

In 2024, a total of 26 typhoons formed in the Northwest Pacific and the South China Sea, one more than the annual average. Nine of them made landfall in China, two more than the annual average. In late July, Typhoon Gaemi brought storms and rains to Fujian and Jiangxi provinces, and its remnants brought extreme heavy rainfall in Hunan Province, leading to severe flooding and geological disasters. The Super Typhoon Yagi in early September was the strongest typhoon to make landfall in China in autumn since meteorological records began, and also the strongest typhoon to make landfall in China in the past decade. It was highly destructive, causing 4 deaths in Hainan, Guangdong, Guangxi, and Yunnan provinces, the collapse and damage of 189,000 houses, and direct economic losses of CNY 72.03 billion. From late October to early November, Typhoons Trami and Kong-rey brought significant impacts through storms and rains on many areas of Hainan Province and East China without making landfall on the Chinese mainland. In 2024, typhoon disasters affected 11.536 million people to varying degrees, resulting in 18 deaths, the emergency relocation of 962,000 people, the collapse of 3,000 houses, damage to 195,000 houses, and direct economic losses of CNY 85.34 billion. In addition, in 2024, coastal storm surges in China exhibited heightened intensity and destructiveness, with some areas flooded with seawater, affecting over 3,400 people across five provinces (regions) including Hebei, Liaoning, Zhejiang, Guangdong and Guangxi, resulting in the direct economic losses of CNY 72 million.

2.3 Frequent severe convective weather and widespread hail events

In 2024, China experienced 32 regional severe convective weather events. The frequency was high in spring, with some areas experiencing multiple rounds and significant overlapping occurrences. Throughout the year, short-duration heavy rainfall and thunderstorms were more frequent than the average of the past three years, with localized extreme weather events causing severe disaster impacts. Strong tornadoes occurred in Guangzhou, Guangdong Province, and Heze, Shandong Province, resulting in 19 deaths. Lightning disasters caused 47 deaths, mainly occurring in Xizang, Jiangsu, Yunnan, Guangxi, and Qinghai. In 2024, strong wind and hail disasters affected 7.992 million people to varying degrees, resulting in 88 deaths, the emergency relocation of 12,000 people, the collapse of 1,000 houses, the damage of 166,000 houses, an affected area of 1,147,400 hectares of crops, and direct economic losses of CNY 14.57 billion. In addition, in 2024, China experienced 14 sand and dust weather events, including four events classified as sandstorms or above, affecting 302,000 people in four provinces (regions) including Xinjiang, Ningxia, Gansu, and Inner Mongolia, with an affected area of 31,200 hectares of crops and direct economic losses of CNY 220 million.

88 people	12,000 people	1,147,400 hectares	CNY 14.57 billion
Resulting in deaths	Emergency relocation	Affected area	Direct economic losses

2.4 Significant impact of low temperature, freezing rain and snow disasters in Hubei and Hunan in early 2024

In 2024, China experienced a total of 33 cold fronts, of which 4 reached the level of cold wave or above. In February, central and eastern China experienced two major waves of widespread low temperatures, freezing rains, and snowfalls. This event, the most severe of its kind since 2009, was notable for its long duration, extensive impact, heavy rainfall and snowfall intensity, and complex mix of precipitation types. The severe weather, coinciding with the Spring Festival travel rush, severely disrupted road traffic, power supplies, public travel, and daily life. Excessive snow loading induced building collapses in some areas, resulting in casualties. Hubei and Hunan provinces suffered the most severe impacts, with disasters affecting 5.67 million people and causing nine deaths. In addition, avalanche disasters caused ten deaths in Altay, Xinjiang, and Nyingchi, Xizang. In 2024, low temperature, freezing rain and snow disasters affected 9.07 million people to varying degrees, resulting in 24 deaths. About 504,000 people required emergency living assistance, with a disaster-affected area of 958,900 hectares of crops and direct economic losses of CNY 25.62 billion.

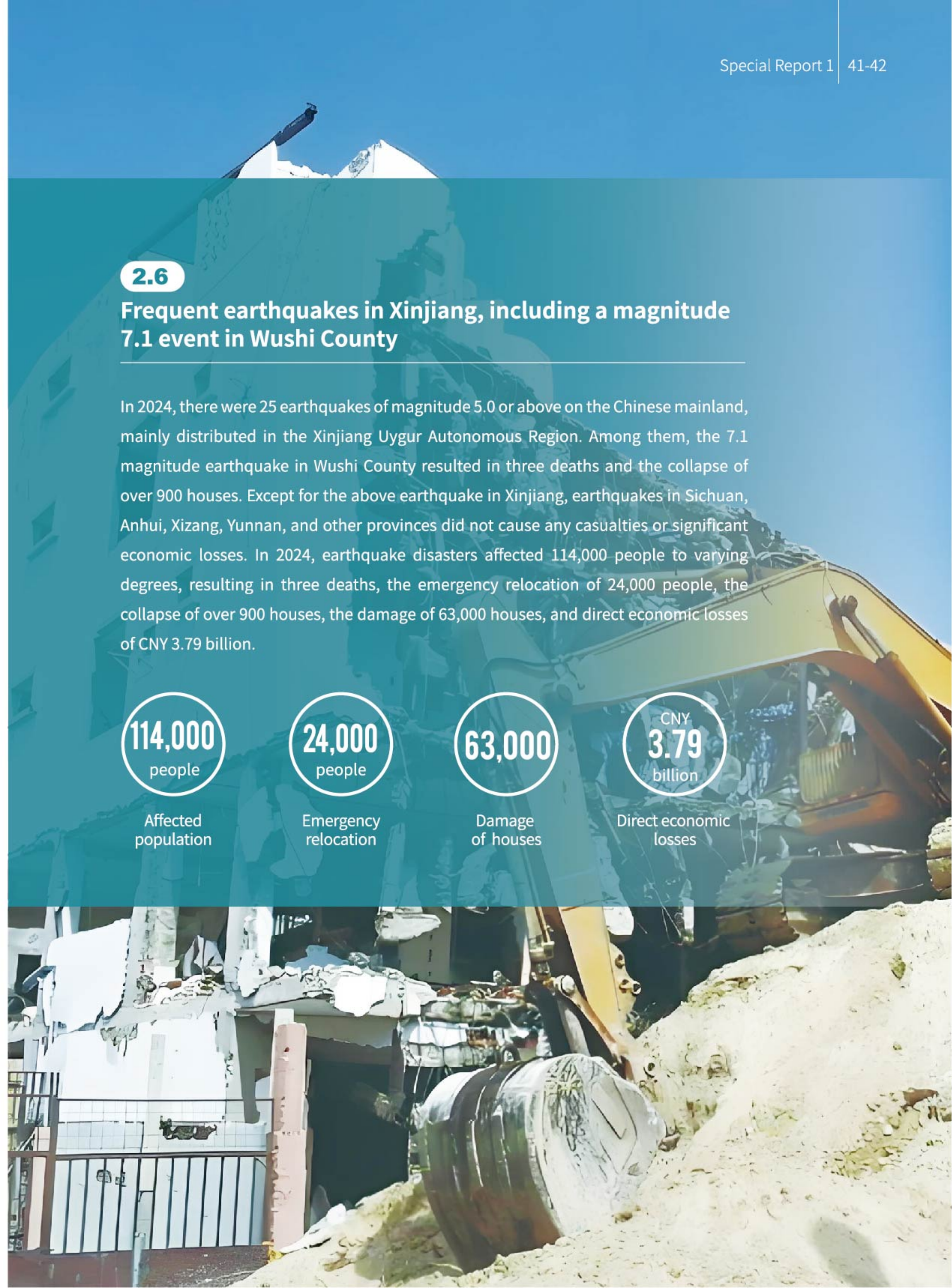
9.07 million	504,000 people	958,900 hectares	CNY 25.62 billion
Affected population	Required emergency living assistance	Cropland affected area	Direct economic losses

2.5

Phased-specific drought conditions with overall modest disaster impacts

At the beginning of 2024, the southwestern region experienced continuous below-average rainfall and insufficient water storage in reservoirs, leading to a winter-spring drought. After the flood season began, the drought was gradually alleviated due to multiple rounds of heavy rainfall. From May onwards, a period of sustained high temperatures across North China, the Huang-Huai, and Jiang-Huai regions accelerated soil moisture depletion and the onset of drought conditions. In mid and late June, the rain belt moved northward, gradually alleviating drought conditions in most areas, while some regions experienced rapid transitions between drought and flooding. From August, influenced by high temperatures and scanty rainfall, Sichuan, Chongqing, and the middle reaches of the Yangtze River experienced late summer and early autumn droughts, which persisted until October when they were largely alleviated. In 2024, 11.491 million people were affected by drought disasters to varying degrees, with 1,206,200 hectares of crops affected and direct economic losses of CNY 8.36 billion.

11.491 million people	1,206,200 hectares	CNY 8.36 billion
Affected population	Cropland affected area	Direct economic losses



2.6

Frequent earthquakes in Xinjiang, including a magnitude 7.1 event in Wushi County

In 2024, there were 25 earthquakes of magnitude 5.0 or above on the Chinese mainland, mainly distributed in the Xinjiang Uygur Autonomous Region. Among them, the 7.1 magnitude earthquake in Wushi County resulted in three deaths and the collapse of over 900 houses. Except for the above earthquake in Xinjiang, earthquakes in Sichuan, Anhui, Xizang, Yunnan, and other provinces did not cause any casualties or significant economic losses. In 2024, earthquake disasters affected 114,000 people to varying degrees, resulting in three deaths, the emergency relocation of 24,000 people, the collapse of over 900 houses, the damage of 63,000 houses, and direct economic losses of CNY 3.79 billion.

114,000 people	24,000 people	63,000	CNY 3.79 billion
Affected population	Emergency relocation	Damage of houses	Direct economic losses

2.7

The number of forest and grassland fires remains stable, with increased occurrences of lightning-caused incidents

In 2024, the forest and grassland fire management in China remained generally successful, with a total of 295 forest and grassland fire records, which is at a historical low and represents a decrease of 759 incidents, or 72%, compared to the average of the previous five years. 292 forest fires occurred, resulting in 13 deaths; three grassland fires occurred, with no casualties. Forest fires were mainly concentrated in Inner Mongolia, Guizhou, and Heilongjiang, with the primary zone shifting northward and the peak period for occurrences delaying from March and April in previous years to June. Throughout the year, 113 forest fires were caused by lightning strikes, accounting for 40.8% of fires with identified drivers.

3 Trend analysis of disaster indicators

3.1 Affected population

The affected population by various natural disasters across China has demonstrated an overall downward trend from 2004 to 2024. The affected population in 2024 was 94.1298 million, ranking the lowest since 2004. Compared with the annual mean from 2004 to 2023 (265.71 million, 2008 excluded), these statistics dropped by 64.6%.

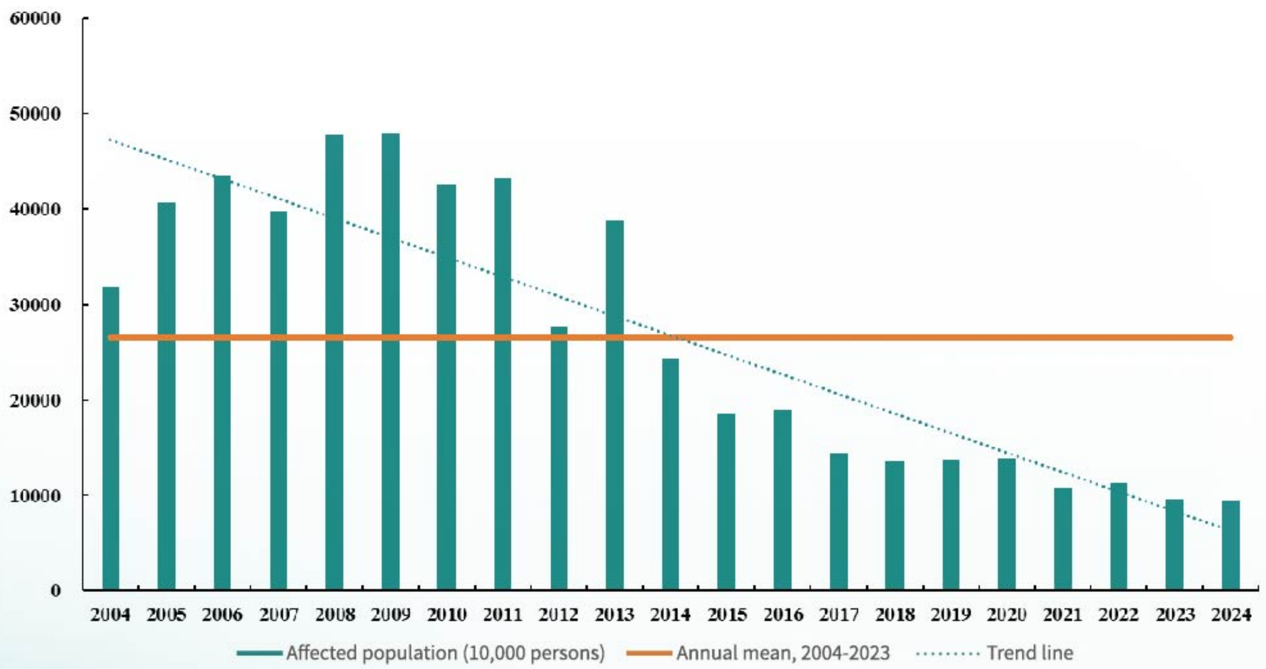


Figure 9 Annual statistic of affected population in China, 2004-2024

3.2 Affected population per 100,000 persons

The statistics of the affected population per 100,000 persons have also shown a decreasing trend from 2004 to 2024. In 2024, the number of affected population per 100,000 persons in China was 6,684, which was the lowest since 2004 and dropped by 66.0% compared with the annual mean from 2004 to 2023 (19,669, 2008 excluded).

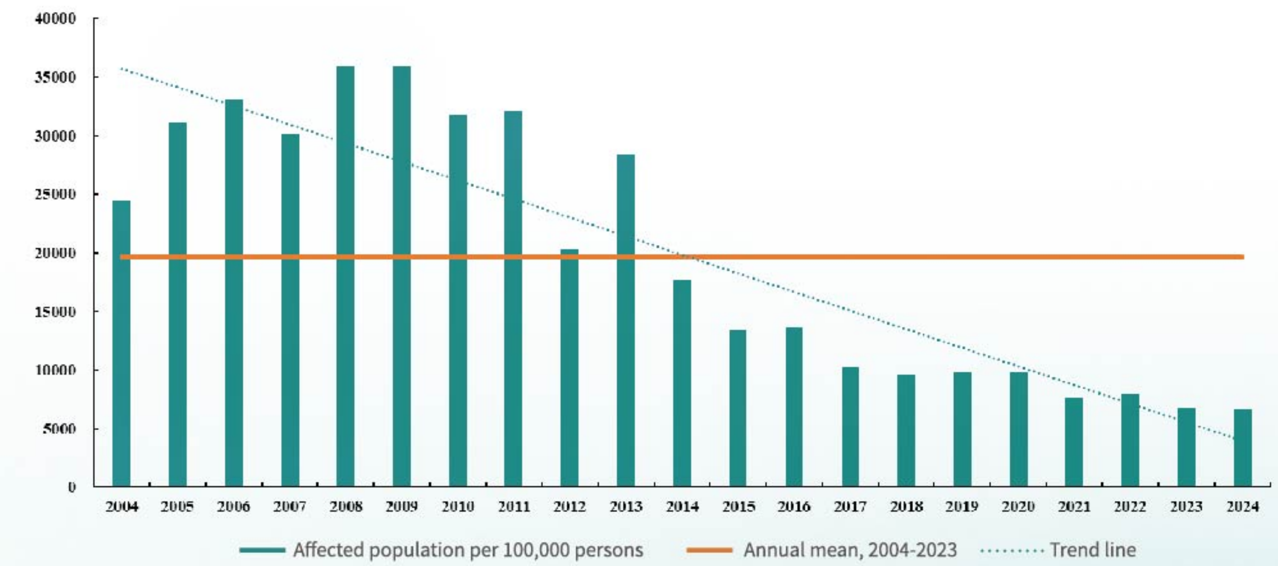


Figure 10 Annual statistics of the affected population per 100,000 persons in China, 2004-2024

3.3 Death and missing tolls

From 2004 to 2024, annual death and missing toll caused by various natural disasters across the country was declining. In 2024, the number of death and missing tolls due to disasters in China was 856, ranking as the fifth lowest since 2004 (only higher than in 2018, 2020, 2022, and 2023), which was a decrease of 52.6% compared to the average number of death and missing tolls due to disasters in China from 2004 to 2023 (1,806, excluding 2008).

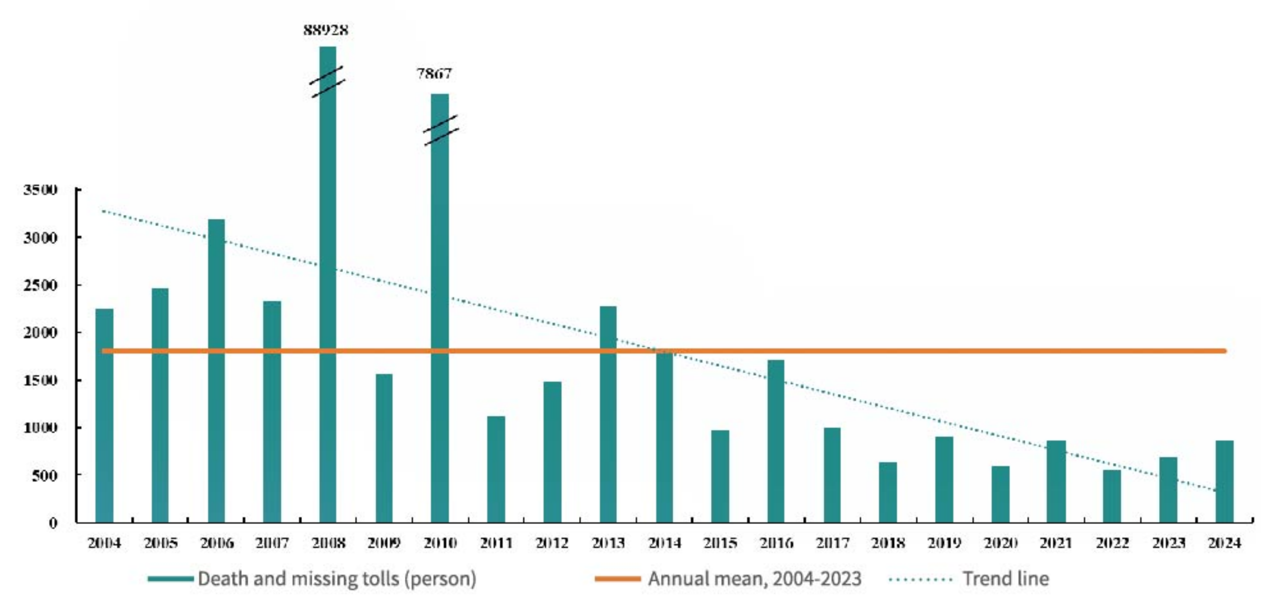


Figure 11 Annual statistics of death and missing toll in China, 2004-2024

3.4 Death and missing tolls per 100,000 persons

From 2004 to 2024, the death and missing tolls per 100,000 persons caused by various natural disasters in China went down as well. The statistics was 0.061 in 2024, ranking as the fifth lowest since 2004 (only higher than in 2018, 2020, 2022, and 2023). Compared to the average from 2004 to 2023 (0.134, excluding 2008), it saw a decrease of 54.6%.

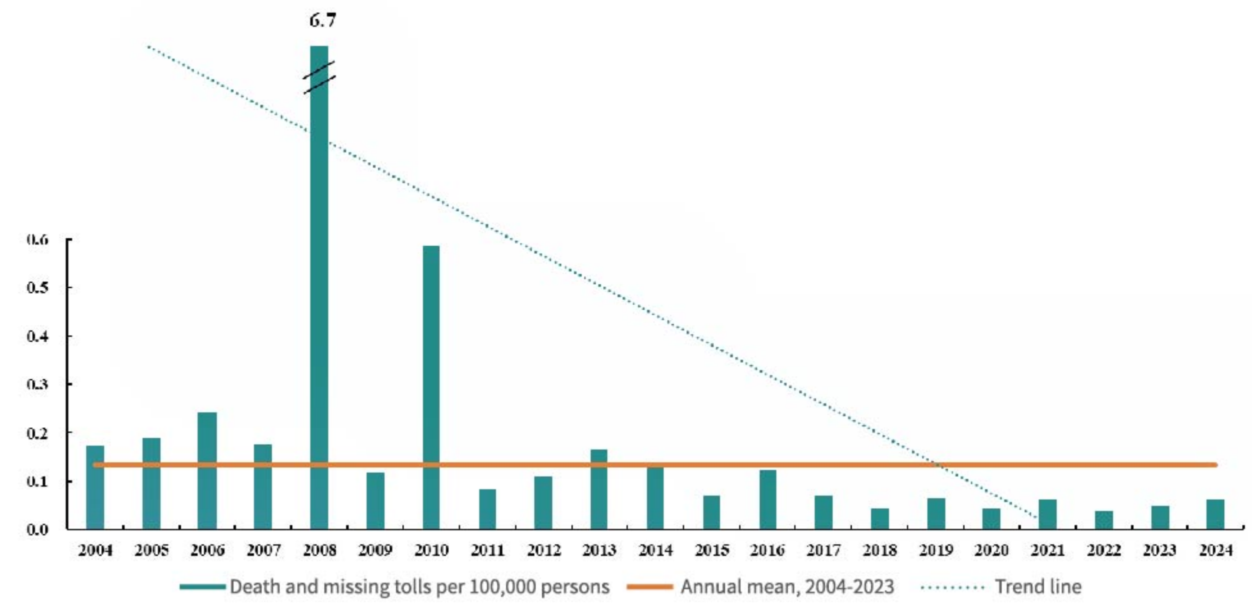


Figure 12 Annual statistics of death and missing tolls per 100,000 persons in China, 2004-2024

3.5 Direct economic losses

From 2004 to 2024, direct economic losses caused by various natural disasters in China showed a downward trend (annual data were converted to comparable prices in 2004 as a baseline according to the GDP index). The direct economic losses in 2024 were CNY 220.11 billion, down 0.8% from the annual mean from 2004 to 2023 (CNY 221.69 billion, 2008 excluded).

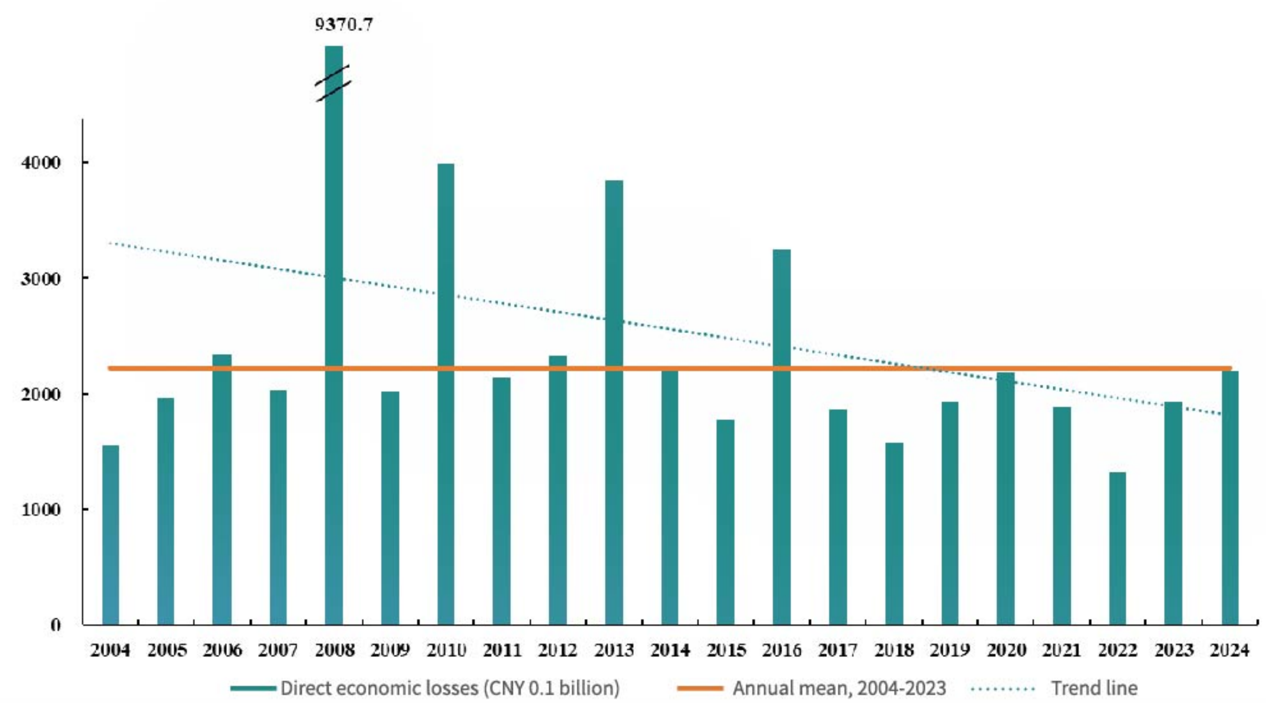


Figure 13 Annual statistics of direct economic losses in China, 2004-2024

(Note: Annual data were converted to comparable prices in 2004 as a baseline according to the GDP index.)

3.6 Direct economic losses relative to GDP

From 2004 to 2024, the ratio of direct economic losses caused by various natural disasters in China over GDP was declining as well. In 2024, the direct economic losses in China accounted for 0.30% of GDP, ranking as the fifth lowest since 2004 (only higher than in 2018, 2021, 2022, and 2023), which was a decrease of 53.1%, compared to the average from 2004 to 2023 (0.63%, excluding 2008).

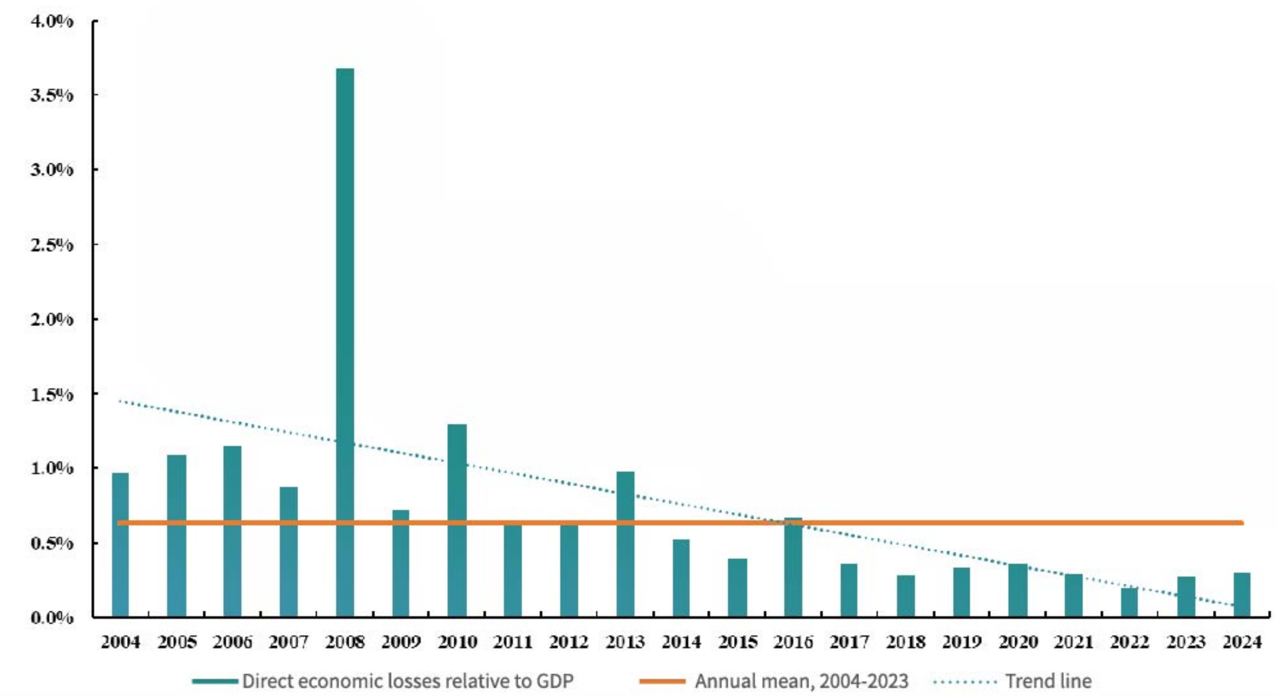


Figure 14 Annual statistics of direct economic losses over GDP in China, 2004-2024

03

Special Report 2
Extreme Heat Events in the Middle East

1. Overview of global climate change
2. Extreme heat events in the Middle East
3. Climate risk analysis in the Middle East and key implications

1

Overview of global climate change

1.1
Overall spatiotemporal characteristics

In 2024, global temperatures reached a new historical high. The World Meteorological Organization (WMO) released the State of the Global Climate 2024, indicating that the global average near-surface temperature in 2024 stood at 1.55±0.13°C above the 1850-1900 baseline, marking it the hottest year on record[2]. Also, the value in 2024 significantly surpassed that of the year 2023 (Figure 1). This represented humanity's first-year breach of the 1.5°C threshold outlined in the Paris Agreement on an annual scale. Although temporarily surpassing this threshold does not mean a complete failure of its long-term goals, it highlights the severe trend of climate warming. As global warming intensifies, the risk of heatwaves brought about by climate change is continuously rising, bringing severe impacts on climate-sensitive sectors such as agriculture, water resources, and human health.

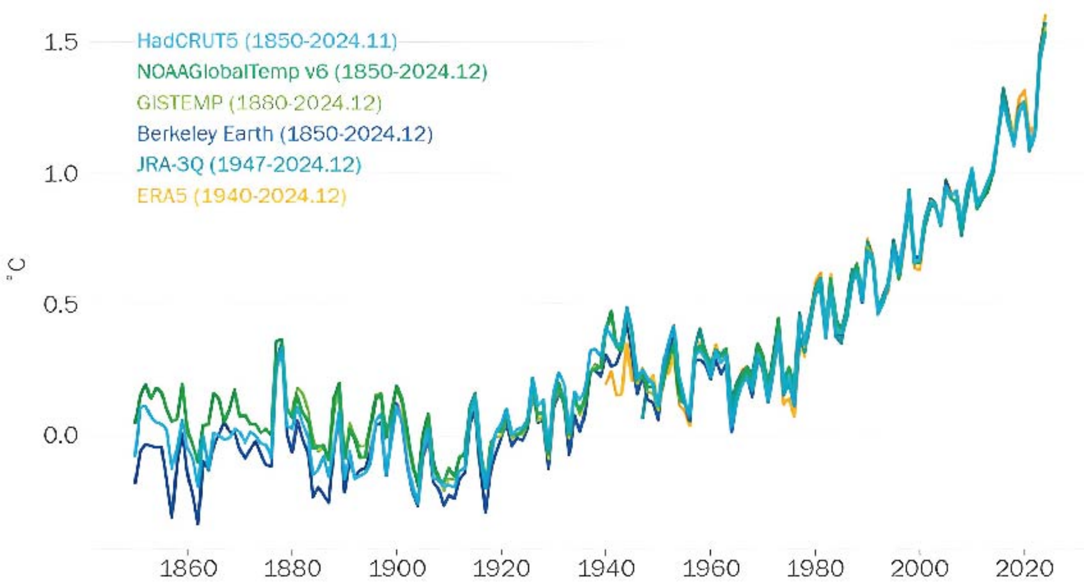


Figure 1 Trend of global average temperature change from 1850 to 2024

[2] Using the global average temperature from 1850 to 1900 as a baseline.

1.2
Spatial variation of high-temperature events

Between 2015 and 2024, global high temperatures exhibited significant regional difference[3]. According to the spatial distribution of high-temperature days globally (Figure 2), high temperatures were observed on every inhabited continent. The only exceptions were Antarctica, the northern Eurasian landmass, the Qinghai-Xizang Plateau, northern North America, and the mountainous western regions of South America. Regions including the Sahara Desert in Africa, the southern Arabian Peninsula, the Indian subcontinent, northern Oceania, and the Paraguay Basin and the Campos grasslands in South America had the highest average number of high-temperature days(2015-2024)—over 210 annually. In contrast, most of Europe, northern Asia, and the eastern plains of North America had the fewest average high-temperature days, with fewer than 15 days.

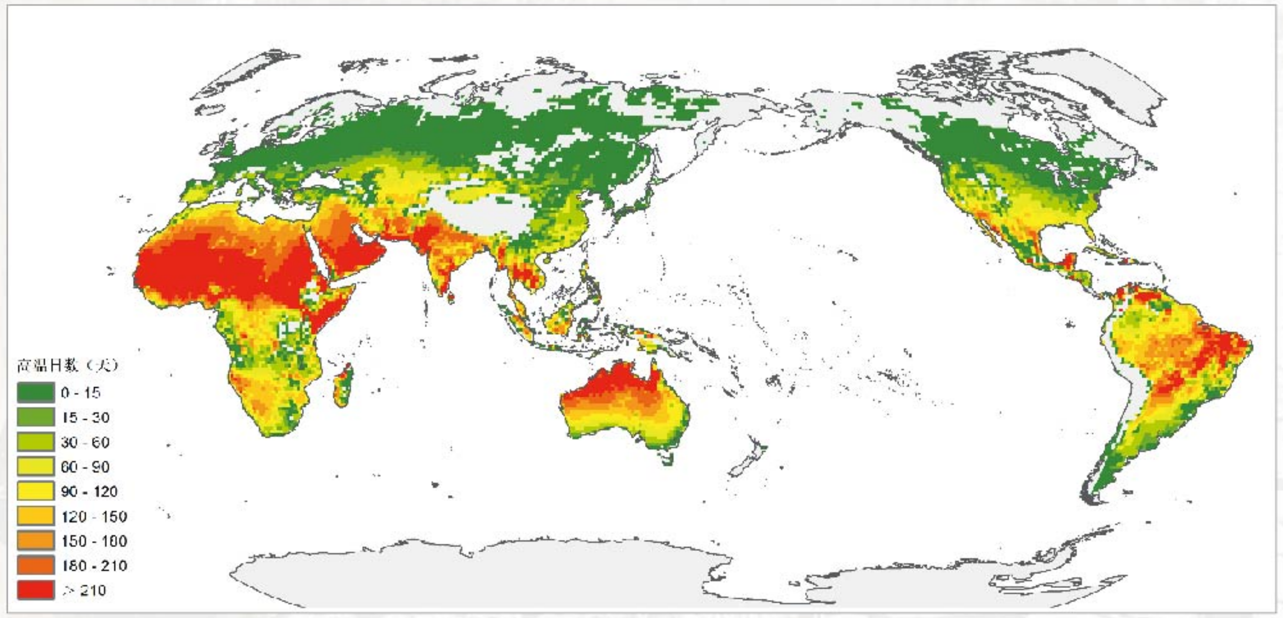


Figure 2 Spatial distribution of annual average high-temperature days globally from 2015 to 2024

[3] Using the high-temperature heatwave standards recommended by the World Meteorological Organization (daily maximum temperature >32°C, sustained for more than 3 days), an analysis of the spatiotemporal characteristics of global high-temperature heatwaves from 2015 to 2024 was conducted based on the ERA5 reanalysis dataset from the European Centre for Medium-Range Weather Forecasts (ECMWF). The data used includes daily maximum temperatures from 2015 to 2024, with a spatial resolution of 1°, and the world population data comes from the LandScan 2023 global population grid data released by the Oak Ridge National Laboratory (ORNL) of the U.S. Department of Energy.

With regard to the ten-year average daily maximum temperatures globally (Figure 3), southern Europe, southern Asia (excluding the Qinghai-Xizang Plateau), Africa, southern North America, South America (excluding the western mountainous region), and Oceania all have daily maximum temperatures greater than 32°C. Regions including West Asia, South Asia, northern Africa, and Oceania experience daily maximum temperatures exceeding 40°C.

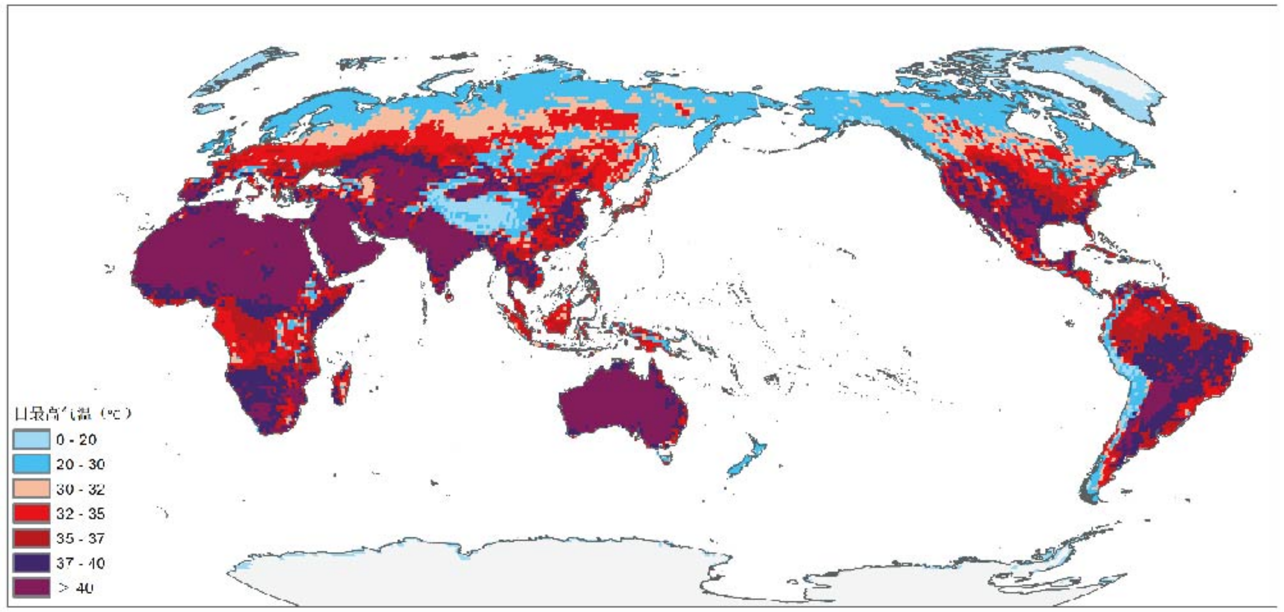


Figure 3 Spatial distribution of average daily maximum temperatures globally from 2015 to 2024

2

Extreme heat events in the Middle East

2.1 Extreme high-temperature conditions across the Middle East

The Middle East is characterized by a hot and dry climate. Under the influence of global warming trends, extreme heat events in this region in 2024 have broken the historical records in terms of peak temperatures, duration, and the synergistic effects of heat and humidity, fully exposing the significant vulnerabilities of the public health system and infrastructure operations in the context of climate change, serving as an important warning case for the global climate crisis.

In terms of temperature intensity, since the beginning of summer in 2024 (from May to June), several countries along the Persian Gulf had experienced persistent extreme high-temperature weather, with daily maximum temperatures in Saudi Arabia, Kuwait, the United Arab Emirates (UAE), and Iraq exceeding 50°C. During the Hajj period (mid-June), in Mecca, Saudi Arabia a historical extreme temperature of 51.8°C was recorded. In terms of duration, the high-temperature period in the Middle East in 2024 spans from early May to mid-July, covering the entire period from late spring to midsummer (Figure 4).

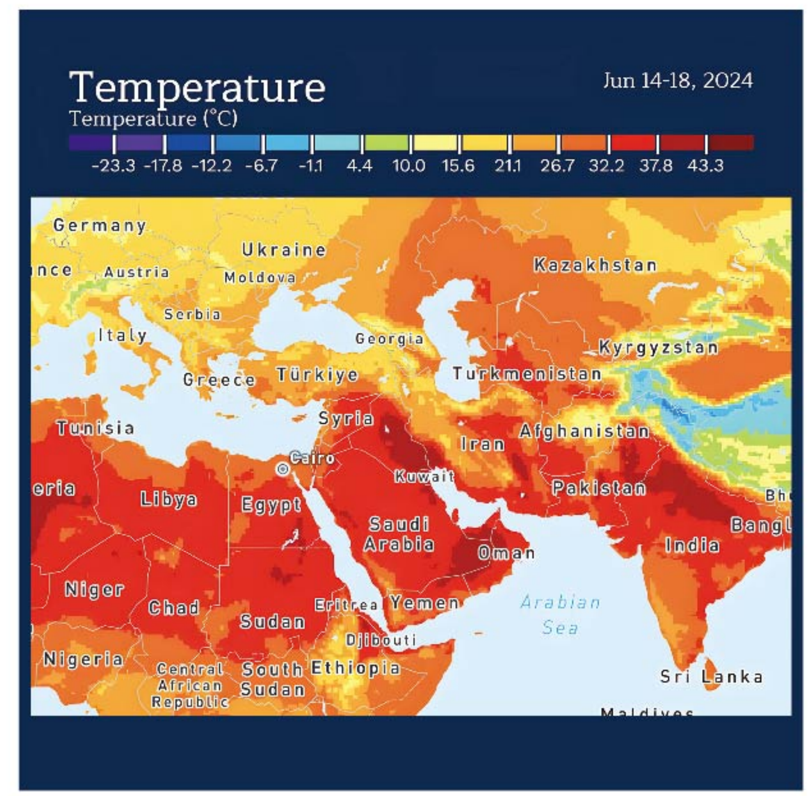


Figure 4 Distribution of high temperatures in the Middle East in mid-June, 2024

After July, the whole Middle East was controlled by the exceptionally strong subtropical high-pressure system, leading to a significant increase in air humidity and the formation of "high temperature and high humidity" compound disastrous weather, further exacerbating the high temperature situation. For example, in Dubai, when the actual temperature reached 45°C, the heat index soared to 62°C (Figure 5) due to humidity exceeding 70%, far exceeding the safety threshold[4]. The perceived temperature around the Persian Gulf repeatedly broke the critical value of "extremely risk" for human health (54°C), posing a serious threat to public health and social operations, and reflecting the instability of regional climate systems under the backdrop of global warming.

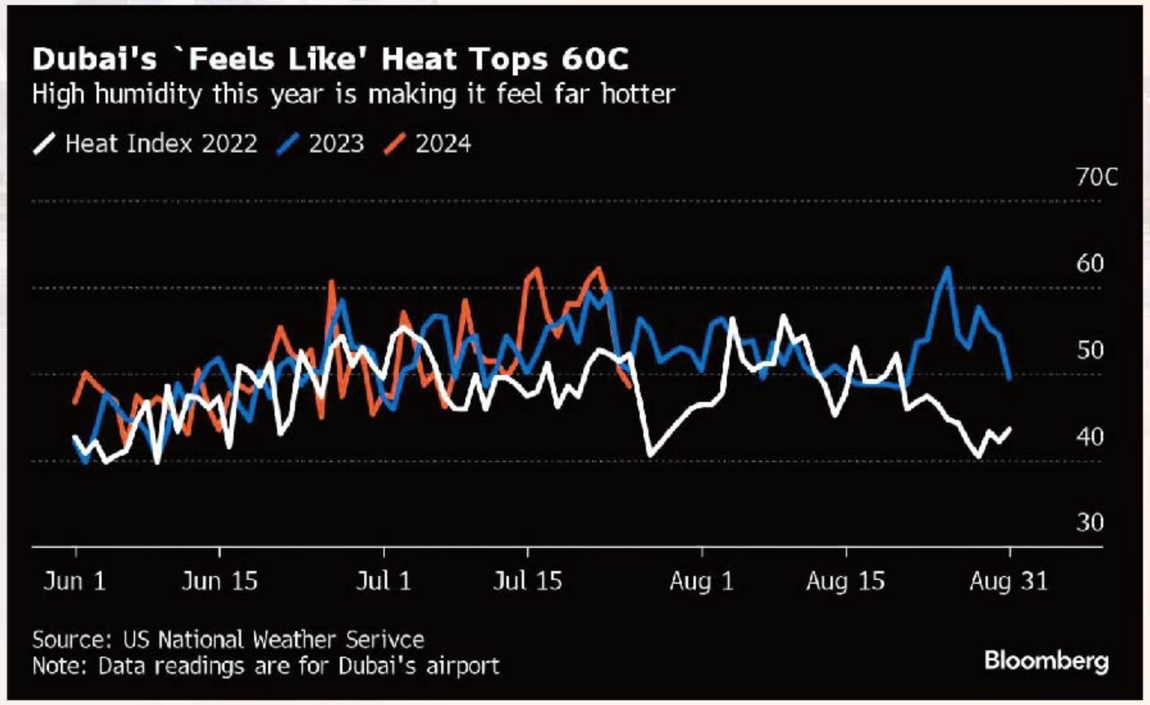


Figure 5 Comparison of heat index values in Dubai in summer, 2022 to 2024

[4] When humidity is too high, the body's heat dissipation function is limited, and a wet bulb temperature exceeding 35°C can be fatal within a few hours.

2.2 Extreme heatwave events during the Hajj pilgrimage in Mecca

Among the extreme heatwave events in the Middle East in 2024, the high-temperature disaster that occurred during the Hajj period in Mecca, Saudi Arabia, was particularly prominent. As one of the largest annual religious events in the world, the Hajj in Mecca in June 2024 attracted over 1.8 million Muslims from around the world. During this period, the Arabian Peninsula was hit by a persistent heatwave, and due to prolonged exposure to high temperatures, it was reported that at least 1,301 pilgrims died from heatstroke and related complications between14 and 19 June, marking the most severe mass casualty event in modern Hajj history caused by extreme weather, resulting in significant humanitarian losses and raising high concerns in the international community regarding the safety of large religious events in the context of climate change[5].

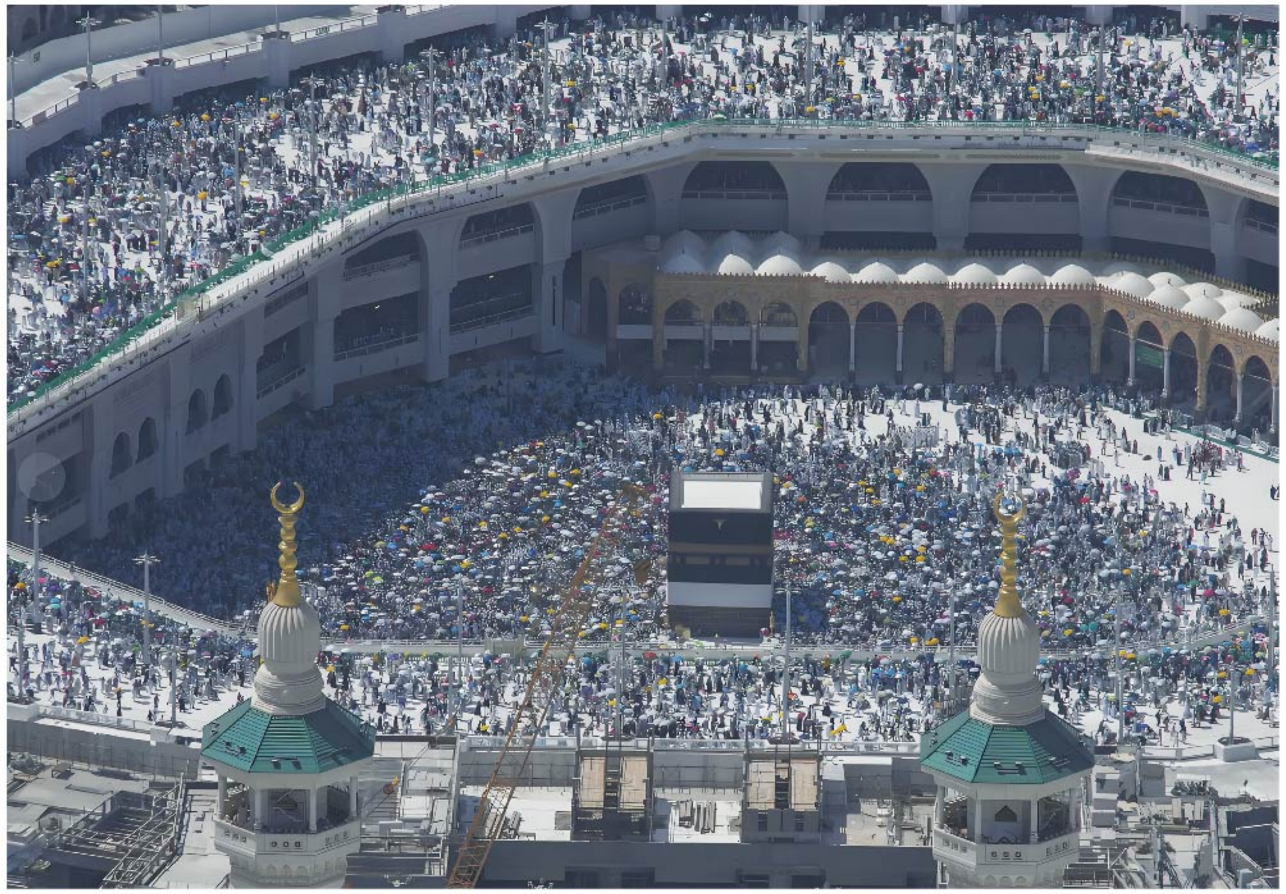


Image source: AP (Associated Press)
https://apnews.com/article/hajj-heat-deaths-mecca-saudi-arabia-pilgrimage-9f97aae1032b14ada29bbea7108195d3

[5] The Hajj is the largest annual gathering of Muslims, held in Mecca, Saudi Arabia, from the 8th to the 10th day of the last month of the Islamic calendar (Dhul-Hijjah). The Hajj in 2024 began on 14 June and ended on 19 June local time.

In this disaster event, the vast majority of the fatalities were informal pilgrims who did not have official permission. The Saudi government implements strict quota management for pilgrimage activities, officially approving approximately 1.8 million pilgrims for 2024. Relevant departments provide standardized services such as air-conditioned tents, cooling water, and medical support. However, due to the total quota control and the high costs associated with official pilgrimage fees, some Muslims travel to Mecca through unofficial channels such as tourist visas, resulting in a large population of undocumented pilgrims. According to statistics from the Saudi Ministry of Health, about 83% of the fatalities in this incident were individuals without official permits. This group generally lacks basic heat protection, and is unable to access official air-conditioned shelters or use dedicated pilgrimage transportation facilities, forcing them to walk long distances in high temperatures and conduct religious activities outdoors, leading to excessive physical exhaustion and a significant increase in heatstroke incidence, making them the main victims of this disaster.

Image source: AFP (Agence France-Presse)
https://www.france24.com/en/live-news/20240620-death-toll-tops-1-000-after-hajj-marked-by-extreme-heat-afp-tally

2.3
Analysis of losses from extreme heatwaves

2.3.1 Casualties and health-related costs

In 2024, extreme heatwave events in the Middle East caused significant casualties, particularly during the pilgrimage in Mecca, Saudi Arabia. Statistics indicate that this event resulted in at least 1,301 deaths, with nearly half being Egyptian pilgrims, along with casualties from over 20 other countries and regions, including Indonesia and Pakistan, highlighting the widespread international impact. Moreover, the heat disaster not only caused numerous fatalities but also triggered a large-scale health crisis. Official data from Saudi Arabia showed that on 16 June alone, more than 2,700 pilgrims received medical treatment for heat-related illnesses such as heat stroke and dehydration. Some patients exhibited severe symptoms including high fever and altered consciousness, with reports of multiple organ failure and sequelae among severe heat stroke cases.

In contrast, while other countries in the Middle East have not experienced concentrated casualties on a similar scale, the systemic impact of high temperatures on public health has become widely evident, primarily manifested in a significant increase in deaths due to illness and a sharp escalation in the pressure on the healthcare system. Firstly, extreme heatwaves exacerbated the incidence of high-risk conditions such as heatstroke, dehydration, and cardiopulmonary diseases, particularly in coastal and inland cities in Iran, Iraq, Egypt and the UAE, where there has been a surge in related patients in emergency rooms and especially in grassroots medical units lacking air conditioning, severely occupying hospital beds and ambulance resources.

Secondly, the medical system is faced with a comprehensive overload during the high temperatures, with a continuous influx of severe cases of heatstroke, dehydration, and respiratory diseases, leading to a shortage of hospital beds and even affecting normal operations. Especially in rural and resource-scarce areas, the shortage of medical personnel and emergency supplies has led to delays in treatment, difficulties in referrals, and declining treatment effectiveness, further straining the public health system.

Moreover, due to the decentralized and non-explicit nature of heat-related deaths, official statistics may be incomplete. Typically, deaths induced by high temperatures, such as cardiac arrest and respiratory failure, are often categorized under existing chronic diseases rather than revealing their temperature context. This pattern of mortality attribution obscures the true impact of heatwaves on public health, suggesting that the actual number of heat-related deaths is likely several times higher than official statistics, reflecting a systematic underestimation of health risks in climate events.

2.3.2 Economic losses and infrastructure impacts

Extreme heatwaves have caused significant damage to the safety of infrastructure and the economic operation system in the Middle East. The energy supply sector bears the brunt. Affected by the sustained high temperature, the regional electricity demand has surged sharply, with multinational power grids operating at record loads, and even some regions approaching the limit of power supply capacity. Once the power system in the Middle East fails in the high temperature environment, it can easily trigger a chain reaction. For example, in 2024, a power plant in Kuwait was paralyzed due to abnormal fuel supply, resulting in the shutdown of commercial establishments, the interruption of industrial production, and the failure of cold chain logistics, leading to secondary disasters such as food and medicine spoilage, with significant direct economic losses.

At the same time, extreme heatwave can cause deformation or even damage to infrastructure such as roads, bridges, and railways. For instance, the asphalt pavements in countries like Bahrain and Kuwait soften under the scorching heat of 50°C, causing noticeable deepening of tire imprints when vehicles pass and frequent repairing demands. Airport runway smoothness has been compromised due to thermal expansion, imposing operational limitations on aircraft takeoff and landing performance. This has forced weight-restricted takeoffs or delays for certain flights, reducing air transport efficiency. High temperatures combined with drought have also led to soil shrinkage, causing frequent pipe bursts in ageing pipelines, and some residential areas have experienced intermittent water shortages, while the pressure in urban water supply systems surges. These issues not only directly increase maintenance costs but also lead to a decline in social operational efficiency, systematically increasing the regional economic burden.

2.3.3 Labor productivity and operational costs

Extreme heat also imposes a dual constraint on economic growth in the Middle East by suppressing labor productivity and increasing operating costs. In the field of labor production, outdoor work is particularly affected by high temperatures. Although the Gulf countries have legislated and implemented a ban on outdoor work at noon in summer, studies showed that when daytime maximum temperatures approach 50°C, even during non-ban periods, workers generally face accelerated physical exhaustion and decreased concentration, leading to reduced output per hour, with some energy-intensive industries even experiencing intermittent shutdowns. Indoor office activities are also indirectly impacted, as deteriorating commuting conditions and fluctuations in power supply due to high temperatures lead to an overall decline in service sector productivity.

In terms of socioeconomic operating costs, expenditures for coping with heatwaves have significantly increased. At the government level, countries need to invest additional financial resources to build public cooling centers, expand emergency medical networks, and implement relief for vulnerable groups to establish a high-temperature defense system. At the enterprise level, to ensure labor safety, outdoor employers generally increase the issuance of high-temperature allowances and provide professional cooling equipment such as ice vests and mobile sunshades, leading to an increase in operating costs in the manufacturing and construction industries. The direct investment and implicit opportunity costs mentioned above have further exacerbated the downward pressure on the regional economy.

2.3.4 Social security and cultural losses

In the summer of 2024, some cities in Iraq experienced local social unrest due to insufficient power and water supply, highlighting the catalytic effect of extreme climate as a “threat multiplier” to regional stability. The high-temperature environment has led to an increase in public anxiety, a sharp decrease in the flow of people in the daytime outdoor activity space, forcing residents to stay in air-conditioned environments for extended periods, significantly reducing their quality of life.

The culture and sports sectors have been significantly impacted, with large events such as summer music festivals and outdoor celebrations in cities like Abu Dhabi and Riyadh either being rescheduled to nighttime or canceled, resulting in direct economic losses for the organizers and further exacerbating the decline in social activities. Such situations have forced countries to invest additional administrative resources to strengthen social governance, significantly increasing implicit governance costs.

Extreme heatwaves also bring intangible social and cultural impacts, including disruptions to religious and cultural activities and psychological shocks to society. The Hajj pilgrimage in Mecca is sacred and solemn in the eyes of Muslims, but the casualties in 2024 have impacted the religious sentiments of Muslims worldwide and cast a shadow over this sacred tradition. The large-scale loss of life not only constitutes a family tragedy but also triggers widespread grief in the Islamic world, potentially affecting believers' willingness to participate in the summer pilgrimage for a long time[6]. Saudi Arabia's international reputation as the “Guardian of the Two Holy Mosques” and the pilgrimage-related industry chain face potential challenges. Attention should be paid to the systemic impact of extreme climate on the transmission of religious culture and the associated economic ecosystem.

[6] From 2015 to 2024, the proportion of summer pilgrimages is 40%, but it will drop to about 13% in the next 30 years.

3

Climate risk analysis for the Middle East and key implications

As one of the regions with the highest climate risk globally, the Middle East exhibits significant characteristics of systemic, compound, and cross-border transmission, facing multiple threats such as extreme heatwaves, water resource shortages, severe sandstorms, and rising sea levels, which create cross-border spillover effects through ecological chains, trade networks, and geopolitical channels. Currently, the climate risks in the Middle East are deeply intertwined with regional governance deficiencies and socio-economic conflicts, forming a vicious cycle of "environmental degradation-resource competition-security instability", posing comprehensive challenges to sustainable development.

3.1 Climate exposure risks in the Middle East

In terms of exposure, the climate risks in the Middle East are characterized by high hazard intensity, long duration, and wide impact range. Firstly, regarding temperature value, the Mitribah weather station in northern Kuwait recorded a historic high temperature of 54°C on 21 July, 2016, recognized by the WMO as the highest temperature recorded in the Asian continent. In the summer of 2024, the maximum temperature in the Jehra area of Kuwait exceeded 50°C for eight consecutive days, with nighttime minimum temperatures sometimes exceeding 35°C, and the average temperature being 6-8°C higher than normal.

Secondly, in terms of duration, taking Kuwait as an example, from 1962 to 1999 (over 37 years), there were only 18 days with daily maximum temperatures reaching or exceeding 50°C; in contrast, from 2000 to 2021 (over 22 years), this number increased to 80 days (with 64 days recorded in the 12 years from 2010 to 2021), indicating a significant upward trend in the frequency of extreme heatwave events. A joint study by the Max Planck Institute for Chemistry and the Nicosia Research Institute in Cyprus indicates that even if greenhouse gas emissions begin to decline after 2040, the Middle East may still face an average of 118 days of abnormally high temperatures per year by the end of the 21st century.

Furthermore, the extreme heatwaves in the Middle East demonstrated significant transboundary impacts, evolving from country-specific events to regional events with transboundary climate risks. According to observations from the European Centre for Medium-Range Weather Forecasts (ECMWF), the extreme heatwave in June 2024 extended across the entire Arabian Peninsula to the coasts of the Red Sea and southern Iran (Figure 6), forming a continuous heat belt spanning approximately 2,000 kilometers from east to west. This highlights the cross-border correlation of heatwaves in spatial distribution and reflects that such events, under the context of climate change, have become a regional governance issue that requires multinational coordination and cooperation.

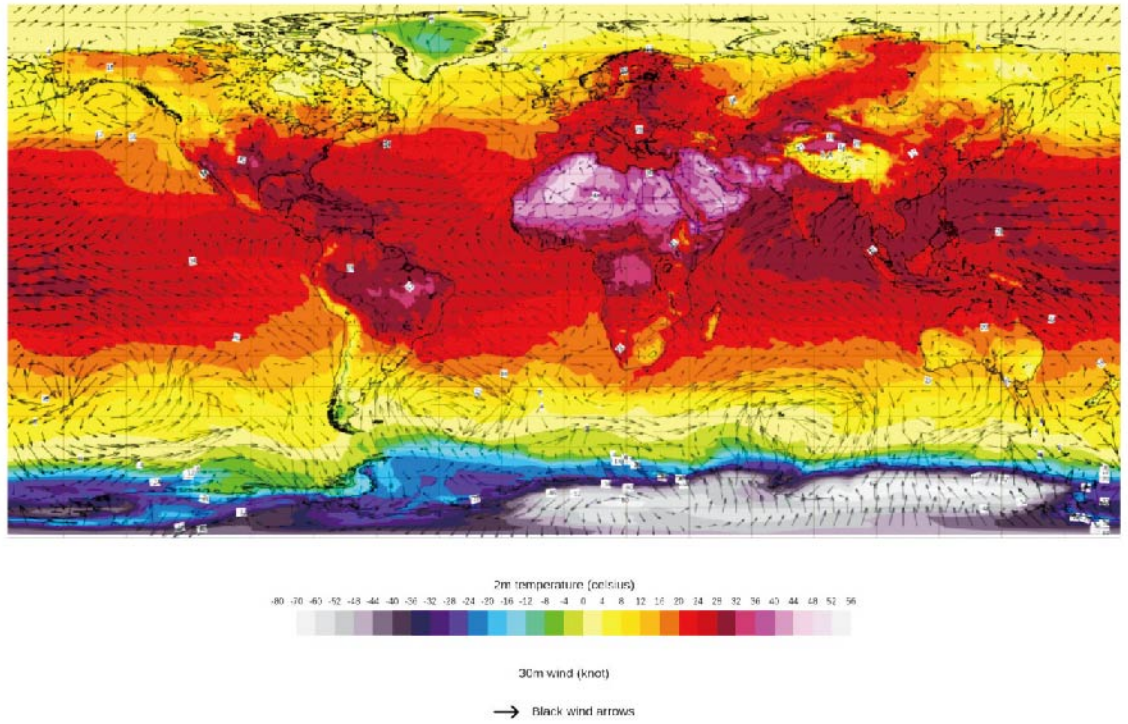


Figure 6 Schematic of heatwave coverage in the Middle East (June 28, 2024)

3.2

Climate sensitivity risks in the Middle East

In terms of sensitivity level, the vulnerability of the economic structure and public health system in the Middle East amplifies the impact of climate hazards, making the region increasingly sensitive to health crises caused by heatwaves. Taking Kuwait as an example, from 2010 to 2019, Kuwait recorded a total of 263,182 cases of cardiovascular hospitalizations, of which approximately 20,569 cases (about 7.8%) were attributable to high temperatures. Research showed that when temperatures exceed 41°C, the hospitalization rate for cardiovascular diseases (CVD) in the country increases by 29.2% compared to the minimum incidence temperature (approximately 20.7°C); when temperatures exceed 43°C, the risk further rises to 32.6%. The study also indicated that migrant workers in Kuwait experience myocardial infarction cases at 2-3 times the rate of local residents when exposed to environments exceeding 41°C.

These data reflect the high sensitivity of public health systems in Middle Eastern countries to heatwaves. Heatwaves not only directly exacerbate chronic disease deterioration but also lead to outbreaks of heat-related diseases, due to the limited access to air conditioning, cold facilities, and public medical support in the impoverished communities and low-income temporary labors, , which inflict severe health damage among these vulnerable groups.

3.3

Climate adaptation risks in the Middle East

In terms of climate adaptation capacity related to heat health, there are significant gaps in the current adaptation systems of Middle Eastern countries. Currently, the average heat-related death rate in the entire Middle East and North Africa (MENA) region is 2.1 per 100,000 persons. Under the worst high-emission scenario, this figure is projected to soar to 123.4 per 100,000 by 2100, while if global warming is kept below 2°C, the death rate will be controlled at 20.3 per 100,000. Some Middle Eastern countries, although equipped with cooling infrastructure (such as centralized cooling systems), have seen almost no widespread deployment of heat health warning systems within their health systems, and have a low coverage of public cooling facilities, and a lack of supporting emergency medical response and heat-stroke specialty resources.

At the level of national policy coordination and regional resource integration, the Middle East lacks a shared monitoring mechanism for heat-related diseases, unified standards for death attribution, and a transboundary medical support network, which directly undermines the overall emergency response efficiency in the region. Meanwhile, although countries like Egypt, Jordan, and the UAE have developed their National Adaptation Plans (NAPs) for climate, public health remains unprioritized. These plans predominantly focus on agriculture, water resources, and infrastructure, leaving very limited responses to health systems challenges, especially those related to extreme heatwaves.

3.4

Insights and recommendations

3.4.1 Risk of heatwaves

As global climate change intensifies, various extreme weather events are occurring frequently worldwide, with increasingly significant impacts on human society. The risk of heatwaves is gradually becoming a major threat to human survival and development. Extreme heatwaves not only highlight the vulnerability of urban ecological environments but also hinder socio-economic development, increase social discontent, and raise the risk of social conflict. In urban areas, flammable and explosive materials exposed to prolonged high temperatures are prone to fires or even explosions, releasing toxic substances that severely pollute the air.

This will threaten the stability of urban ecosystems, negatively impact urban energy supply and industrial production, exacerbate discomfort in urban environments and trigger public anxiety and aggressive behavior. At the same time, extreme heatwaves increase the incidence and mortality rate of cardiovascular diseases, respiratory diseases, heat stroke, and other health issues, while also increasing people's psychological burden. These health emergencies will exacerbate the scarcity of medical service equipment and facilities, especially in the context of high urban population density, where vulnerable groups such as the elderly and children are more susceptible to the impacts of extreme heatwaves.

To effectively address the challenges posed by extreme heatwaves to human life, property safety, and the stable operation of cities, it is necessary to adopt integrated approaches from multiple perspectives, including adaptability, mitigation, and inclusiveness. This will ensure equal participation and shared risk governance benefits for all individuals, including vulnerable groups. To enhance the resilience of cities against extreme heatwaves, it is essential to incorporate responses to extreme heat events into the overall urban disaster risk reduction strategies and actions. This includes establishing a comprehensive mechanism for "forecasting-early warning-response-recovery", to improve risk identification and assessment mechanisms, strengthen the resilience of urban infrastructure, enhance the adaptability of urban buildings to extreme heatwaves, and increase public education on disaster risk knowledge and responses to raise public awareness of and highlight the importance of preparing for extreme heatwaves.

At the same time, it is proposed that the Middle East can build a climate resilience network through regional, multilateral and global cooperation and governance. At the regional level, existing frameworks such as the Gulf Cooperation Council (GCC) and the Arab League can be leveraged to establish a transboundary heatwave early warning system, standardizing heatwave indicators and emergency response procedures. Under multilateral mechanisms, efforts could be made to promote the establishment of some special fund mechanisms for climate health within the framework of the United Nations Framework Convention on Climate Change (UNFCCC), specifically supporting the transfer of heat adaptation technologies and training for public health personnel. Additionally, a regional health risk monitoring database for heat can be constructed using the World Health Organization (WHO) network to enable transboundary data sharing. In the global level, it is advocated to include the heat risk in the Middle East in the climate and energy cooperation agenda of the Group of Twenty (G20), transforming climate risk responses into a bond for regional peace and development through cooperation with emerging economies on the South-South cooperation platforms, ultimately forming a collaborative network of "joint technology research-shared resource management-collective risk prevention".

3.4.2 Large-scale religious activities or mass gatherings

To effectively reduce public safety risks during future heatwave events similar to those experienced during the Hajj pilgrimage in Mecca, a systematic emergency system for organizing large cultural activities under extreme climate conditions needs to be established. This requires optimizing operational procedures and addressing the vulnerabilities and management gaps in such activities during extreme weather. Such a system includes, but is not limited to, expanding and standardizing the pilgrimage permit system, improving on-site infrastructure, enhancing medical and health emergency response capabilities, and upgrading real-time risk management capabilities.

Specifically, given the reality of unauthorized pilgrims, it is suggested to consider expanding the official pilgrimage quota or reducing fees to allow more people to participate through formal channels. If this issue cannot be solved in the short term, a provisional management system should be established for unauthorized individuals, including providing emergency cooling tents and water supply stations to prevent them from being completely unmanaged. Permanent or temporary cooling facilities can be added along pilgrimage routes and gathering places, and air-conditioned shuttle buses can be increased to prevent vulnerable individuals from suffering heatstroke due to long-distance walking. The medical team for the pilgrimage needs to be expanded, with more medical shelters and mobile emergency teams deployed in densely populated areas, equipped with sufficient supplies for heatstroke emergencies, such as ice water, ice blankets, and ice caps. Additionally, meteorological threshold management can be implemented, whereby special protective measures, such as water mist spraying for cooling, would be activated when temperature/humidity exceeds certain critical values.

04

Special Report 3

Assessment of Cross-Border Economic Impacts from Typhoon Yagi

1

Disaster background and overview

In recent years, the compounding effects of global climate change and the accelerated process of urbanization have led to extreme weather events that break historical records, exceed existing defense standards, and challenge scientific expectations. These events have resulted in significant casualties and economic impacts. The Global Risks Report 2024, published by the World Economic Forum (WEF), highlights that climate change has been triggering complex meteorological disasters such as droughts, wildfires, tropical storms, and heatwaves, thereby positioning extreme weather events among the top global risks for the coming decade.

In September 2024, Super Typhoon Yagi affected multiple countries across East and Southeast Asia, causing substantial human and economic losses. The system formed over the waters east of the Philippines on the evening of 1 September. Its first landfall occurred in Casiguran, Aurora Province, northeastern Philippines, on the afternoon of 2 September, after which it continued to intensify[7]. On 6 September at 16:20 local time, Yagi made landfall near Wengtian Township, Wenchang City, Hainan Province, China, at near peak intensity (68 m/s).That evening at 22:20, it made landfall in the coastal area of Jiaowei Township, Xuwen County, Guangdong Province, China. On 7 September at 15:30, it made landfall in the southern coastal area of Quang Ninh Province, Vietnam, as a super typhoon (58 m/s). This typhoon caused 21 deaths, 22 injuries, and 26 missing persons in the Philippines. In China, 2.75 million people across four provinces were affected to varying degrees, with direct economic losses amounting to CNY 72 billion[8]. In Vietnam, 3.6 million people were affected, 280 people died, and direct economic losses exceeded VND 81 trillion[9].

The deep integration of transportation networks and waterway channels between China and Southeast Asia has significantly strengthened the coupling of regional industrial and supply chains, thereby expanding the spatial and sectoral scope of losses from extreme disasters and generating cascading amplification effects that underscore systemic risks. The impacts of power supply interruptions, transboundary trade disruptions, effects on the populations, and suspension of transportation and tourism caused by Typhoon Yagi have spread to inland cities in China and Southeast Asian countries through the industrial and supply chains, ultimately exerting systemic impacts on regional economies and even global supply chain.

[7] Philippine Atmospheric, Geophysical and Astronomical Services Administration named it Enteng.
[8] Typhoon Yagi affected 830,000 users' electricity supply. The data is from the official website of the People's Government of Hainan Province.
[9] Statistical report on damages caused by Typhoon Yagi. Ministry of Agriculture and Rural Development of Vietnam. 2025.

2

Cross-regional economic ripple impacts

Typhoon Yagi has generated ripple impacts globally by directly impacting China, the Philippines, and Vietnam. Based on the GTAP (Global Trade Analysis Project) data and ARIO model[10,11], the economic ripple impacts of Yagi on the global supply chain system is approximately USD 62.9 billion, which is 5.51 times the direct economic losses. Typhoon Yagi also shows significant ripple effects in typical countries and regions in Southeast Asia and its surroundings. For the 12 countries in Southeast Asia and its vicinity, the economic ripple effect is approximately USD 13.52 billion, which is 0.97 times the direct losses of China, Vietnam, and the Philippines. The indirect economic impacts in the surrounding 12 countries are equivalent to the direct economic losses caused by Typhoon Yagi. As shown in Table 1, for Southeast Asia and its surrounding areas, excluding China, the Philippines, and Vietnam—the three countries directly struck by Typhoon Yagi—the country most affected by the indirect ripple effects was Australia, with estimated indirect economic losses of USD 1.833 billion. India ranked second, with indirect economic impacts of USD 1.331 billion.

Table 1 Indirect economic impacts in Southeast Asia and some neighboring countries

No.	Country	Indirect economic impacts (USD, hundreds of millions)
1	China	66.26
2	Australia	18.33
3	India	13.31
4	Indonesia	10.57
5	Vietnam	94.30
6	Thailand	62.86
7	Malaysia	61.70
8	Singapore	29.33
9	The Philippines	0.86
10	Laos	0.59
11	Brunei	0.25
12	Cambodia	0.22

[10] Zhang Z, Li N, Cui P, Xu H, Liu Y, Chen X, Feng J. 2019. How to integrate labor disruption into an economic impact evaluation model for Postdisaster recovery periods. Risk Anal. 39 (11), 2443–2456. https://doi.org/10.1111/risa.13365.
[11] Zhang Z, Li N, Cui P, Xu H, Liu Y, Chen X, Feng J. 2019. How to integrate labor disruption into an economic impact evaluation model for Postdisaster recovery periods. Risk Anal. 39 (11), 2443–2456. https://doi.org/10.1111/risa.13365.

Compared to the combined direct and indirect impacts on individual countries, the economic ripple effects of Super Typhoon Yagi on a global scale were even more pronounced. This was primarily attributable to the exceptionally large number of people affected, the sudden reduction in labor supply, and the consequent constraints on industry development. Notably, in Vietnam, the affected population reached 33.8 million, with the death toll and the number of injured being 345 and 1,978, respectively. The labor force has been severely impacted by the disaster, with supply shortages, leading to a significant decline in the intermediate processing capacity of Vietnam's wholesale and retail industry, as well as the metal smelting and related manufacturing sectors (Table 2). These industrial disruptions further influenced global and Southeast Asian trade chains, compounded by Vietnam's advantageous position in global commodity manufacturing and its geographical role as a linkage between northern and southern economies.

Table 2 Indirect economic impacts by industry in Vietnam

No.	Industry	Indirect economic impacts (USD, hundreds of millions)
1	Other mining	13.47
2	Wholesale and retail trade	11.93
3	Other business services	8.93
4	Ferrous metal smelting	7.38
5	Other financial activities	6.79
6	Electric power production and supply	6.78
7	Smelting of other metals	6.02
8	Other non-metallic mineral products	5.97
9	Coal mining	5.79
10	Other transportation	4.78

This assessment is based on the World Input–Output Tables covering 141 countries and 65 economic sectors, as provided by the Global Trade Analysis Project (GTAP) database. Sector-specific evaluation results indicate that the economic ripple impacts of Super Typhoon Yagi on Southeast Asia and its surrounding regions are primarily concentrated in the mining industry and industrial product processing sectors (Figure1).The industry with the highest indirect economic loss, excluding coal, crude oil, and natural gas, is the "other mining industries", with impacts reaching USD 1.367 billion, followed by the wholesale and retail sector, with impacts amounting to USD 1.233 billion. The smelting industry, closely related to mining, also experiences significant indirect impacts from the disaster, with indirect losses in ferrous metal smelting amounting to USD 889 million, ranking fourth among all sectors. Except for Australia, the countries in Southeast Asia and its vicinity are predominantly developing economies undergoing rapid industrialization. Most rely on relatively low-cost labor and resource advantages to drive growth in selected heavy industries and related manufacturing sectors, many of which possess unique and irreplaceable role in foreign trade. The direct shocks caused by disasters and insufficient labor supply often have a significant impact on these industries, which in turn creates further ripple effects on other service industries such as real estate, finance, and transportation. Australia, rich in mineral resources, maintains extensive trade linkages with Southeast Asia. The disruption of Southeast Asia's industrial linkages to global supply chains caused by the disaster has further affected the supply and demand for upstream and downstream products in related sectors.

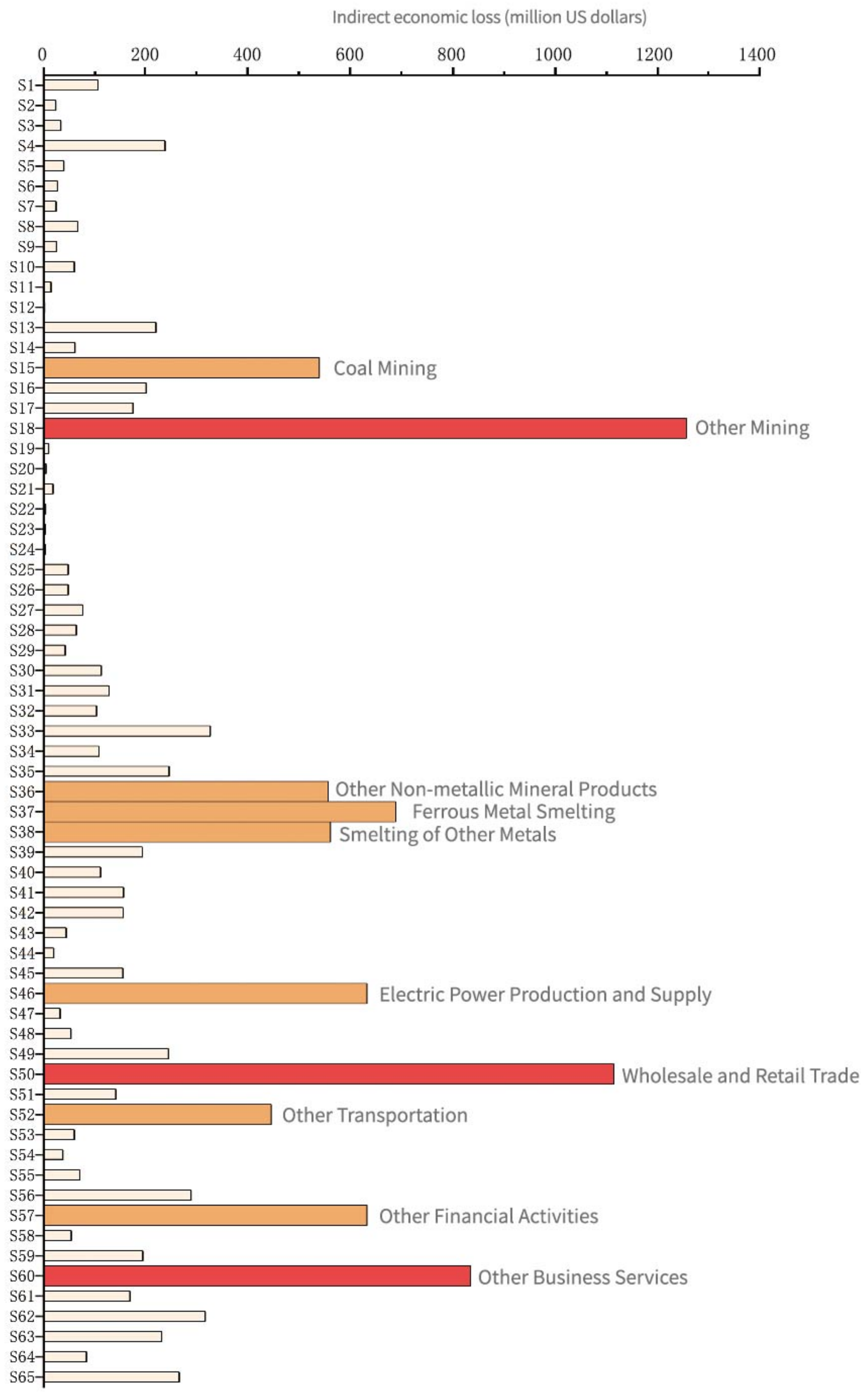


Figure 1 Indirect economic impacts across 65 industries in Southeast Asia and its surrounding areas caused by Typhoon Yagi

(Note: S1 to S65 in the figure are industry codes. Specific industry names can be found in Appendix IV.)

3

Analysis of cascading amplification transmission paths

Based on the Structural Path Analysis (SPA) method, this report extracts and analyzes the cascading amplification paths underlying the global economic ripple effects caused by Super Typhoon Yagi across countries and regions. The SPA method is a flow decomposition analysis method based on input-output tables, which decomposes the production processes of industrial sectors into countless flow paths, thereby reflecting the interrelationships within the economic system. Integrating the SPA method with the overall assessment results, this report analyzes the transmission process of economic impacts across multiple sectors in various regions, while also demonstrating the cascading paths and ripple effects formed in Southeast Asia and its surrounding countries due to the direct impacts of Typhoon Yagi on China, Vietnam, and the Philippines.

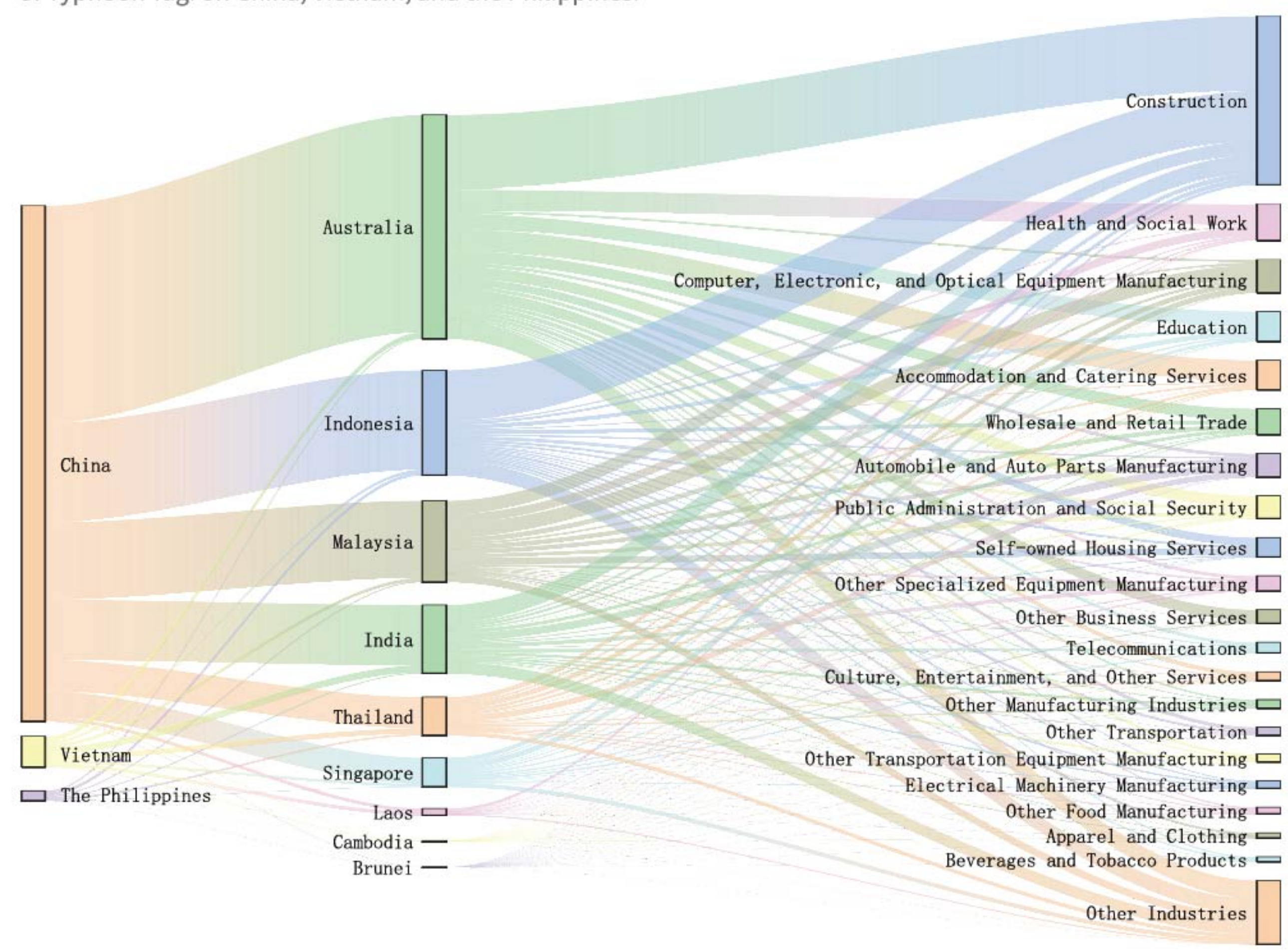


Figure 2 Cascading transmission among various industries in Southeast Asia and surrounding countries

In terms of industrial interconnections, the cascading effects triggered by Typhoon Yagi indicate significant spatial transmission characteristics and industrial correlation patterns. The analysis shows that the impact of the disaster spreads to Southeast Asia and surrounding countries to varying degrees from three main affected countries through the supply chain, forming a three-tiered cascading transmission structure covering approximately 20 key sectors.

According to the path analysis results of the losses caused by Typhoon Yagi in Southeast Asia and its surrounding countries (Figure 2), the construction industry has emerged as a key impact sector in transnational loss transmission. This phenomenon reflects not only the direct damage caused by the typhoon to physical infrastructure, but also highlights the important role of the construction sector and its multi-source product demand within the global industrial chain. For example, disruptions in the supply of building materials in the coastal port areas of southern China may lead to project delays in Australia, Indonesia, and other locations, creating a cross-regional chain reaction. The public service sectors, such as education and healthcare, occupy a significant position in the cascading effects observed in the region. Most countries here face challenge such as insufficient allocation of medical resources and overloaded public health system. In the wake of sudden public service demands triggered by the disaster, some countries struggle to respond in a timely and effective manner due to inadequate financial support and emergency management capabilities, highlighting the chain vulnerability of social service systems in developing countries. Furthermore, influenced by climatic conditions, Southeast Asia and its surrounding countries generally regard tourism as a pillar industry. The typhoon significantly impacts related industries such as culture, sports, entertainment, and tourism services by affecting transportation, accommodation, and dining infrastructure, making it one of the areas most affected by economic loss transmission within the region. This multi-level response structure intuitively reflects the differences in sensitivity of various industries to typhoon disasters, providing important scientific support for formulating targeted regional resilience enhancement strategies.

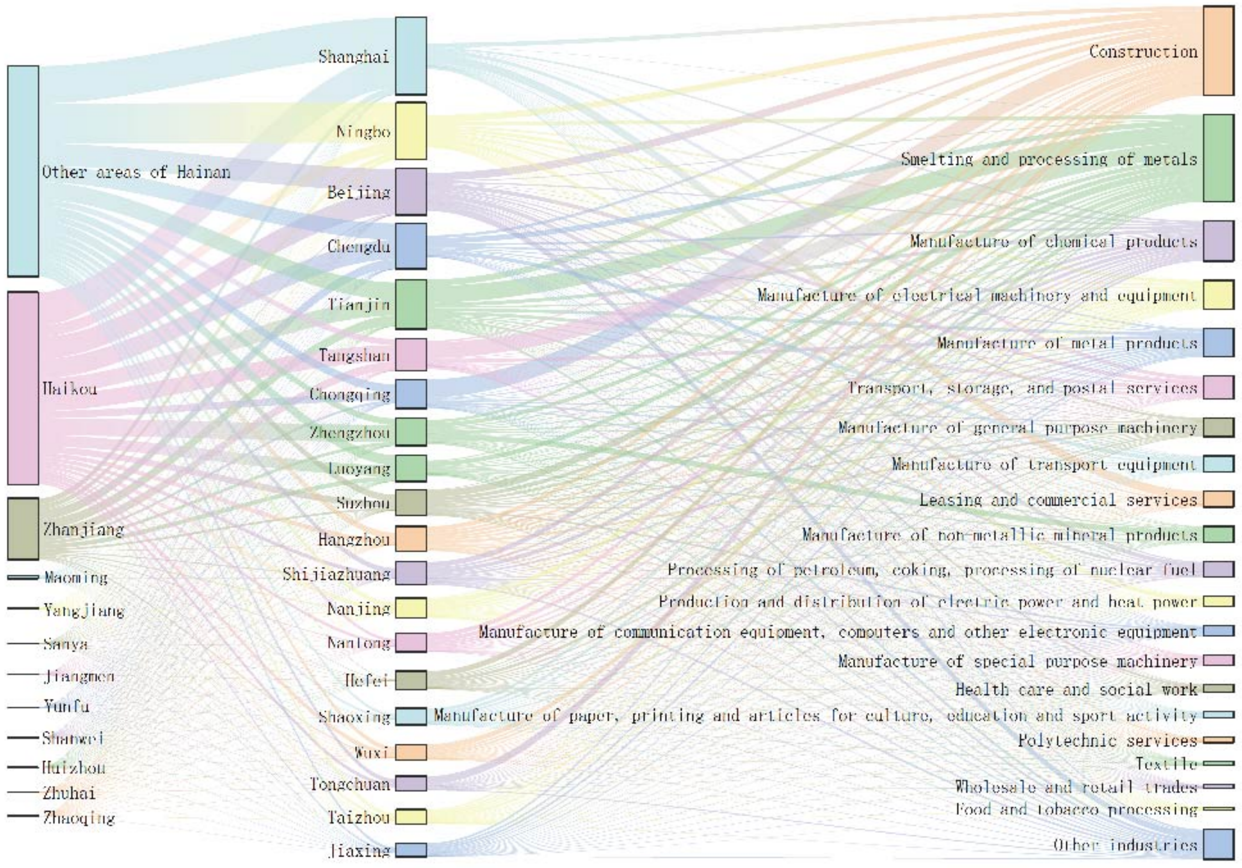
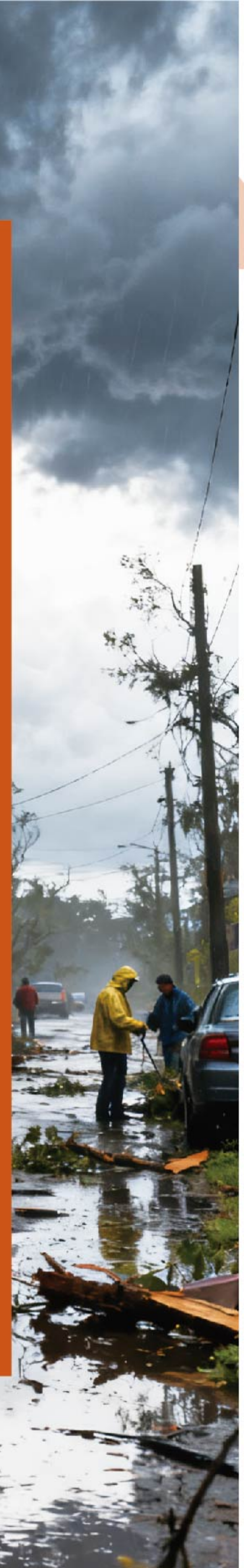


Figure 3 Cascading transmission across various industries in cities in China



In terms of regional connections, the transmission of disaster losses from China, Vietnam, and the Philippines to Southeast Asia and its surrounding areas is closely correlated with the total GDP and major industry trade volumes of the countries in the region. These industry-level cascading paths expose the spatial vulnerability of modern industrial chains—geographical proximity is no longer the dominant factor in disaster transmission, whereas economic interconnectedness is becoming the key transmission medium. Taking the domestic loss path analysis results of one of the directly affected countries, China (Figure 3), as an example, the disaster impact spreads from 17 directly affected cities (mainly distributed in the Pearl River Delta, western Guangdong coastal areas, Hainan economic circle, and eastern Guangdong development axis) to major cities in China. Cities such as Shanghai, Ningbo, and Tianjin, which are home to world-class ports like Shanghai Port, Ningbo-Zhoushan Port, and Tianjin Port for import and export trade, significantly transmit disaster losses to Southeast Asia and its surrounding countries through trade connections.

The path analysis results indicate that the spatial pattern of disaster transmission and the industry chain clearly reflect the systemic risks of the cascading effects. The closure of ports has a systemic chain impact on various manufacturing industries through the transportation equipment supply chain. Disruptions in the tourism service industry and cultural industries create multidimensional economic ripple impacts through regional transportation networks, wholesale and retail channels, and the housing market.

Pearl River Delta | Western Guangdong coastal areas | Hainan economic circle | Eastern Guangdong development axis

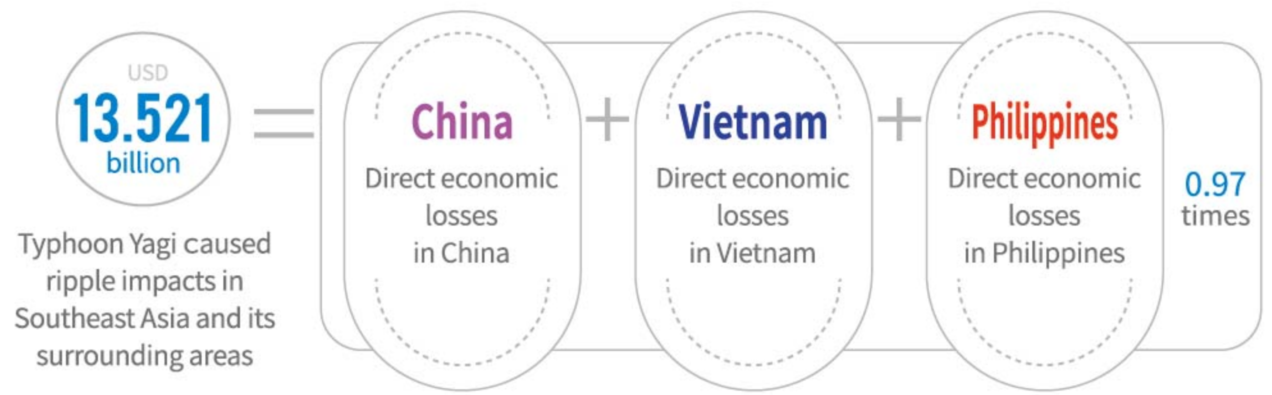
4

Conclusion and discussion

This study focuses on the cross-regional and cross-industry economic ripple impacts caused by the Super Typhoon Yagi on China and surrounding Southeast Asian countries. Systematically assessing the cascading transmission paths of disaster impacts provides theoretical support, methodological references, and empirical cases for deepening research on economic risks from extreme disasters.

Research shows that Typhoon Yagi, through direct damages on China, Vietnam, and the Philippines, caused ripple impacts of approximately USD 13.521 billion in Southeast Asia and its surrounding areas, equivalent to 0.97 times the combined direct losses of the three countries. Australia is the country most severely affected in the region, with the mining and wholesale and retail industries being the main sectors impacted. The cascading transmission process of impacts in the region primarily follows the construction industry as the main transmission path, while social public services and entertainment services also show significant impacts due to the developmental stages and industrial structure characteristics of various countries.

It is noteworthy that the indirect economic impacts caused by Typhoon Yagi have broken through the regional boundaries, generating systemic cascading effects through global supply chain networks. Research indicates that the spatial vulnerability of modern supply chains is pronounced, and the dominant factors in disaster transmission have shifted from geographical proximity to multiple dimensions such as trade linkages, industrial coupling, and transport connectivity. To effectively respond to systemic risk challenges, future disaster risk management needs to transcend the traditional regional limitations and establish a global climate resilience collaborative mechanism based on global supply chains, transportation chains, and trade chains.



Annex I Top 50 Natural Disasters in Terms of Global Fatalities and Direct Economic Losses from 1991 to 2024

Top 50 natural disasters worldwide by death toll, 1991-2024

No.	Time	Affected countries/regions	Type of disaster	Fatalities (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	2023/2/6	Syria, Türkiye	Earthquake	56683	429
8	2010/6-2010/8	Russia	Extreme heatwave	55736	4
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 heatwave	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 heatwave	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 heatwave	15090	8.8
20	1998/10/25-11/8	Honduras	Storm	14600	37.936
21	2023/9/10-9/11	Libya	Storm	12352	62
22	1999/10/28-10/30	India	Storm	9843	25
23	1993/9/29	India	Earthquake	9748	2.8
24	2003/8-2003/8	Germany	Extreme heatwave	9355	16.5
25	2015/4/25	Nepal	Earthquake	8831	51.74
26	2004/12/26	Thailand	Earthquake	8345	10
27	2013/11/8	The Philippines	Storm	7354	100
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 heatwave	3275	0
39	2023/5/2-5/5	Democratic Republic of the Congo	Flood	2970	0.1
40	2010/4/14	China	Earthquake	2968	5
41	2023/9/8	Morocco	Earthquake	2946	70
42	1998/6/9-6/11	India	Storm	2871	4.69
43	1996/6/30-7/26	China	Flood	2775	126
44	2004/9/17-9/18	Haiti	Storm	2754	0.5
45	2003/8-2003/8	Portugal	Extreme heatwave	2696	0
46	2004/5/23-6/1	Haiti	Flood	2665	0
47	2021/8/14	Haiti	Earthquake	2575	16.2
48	2020/6-2020/8	The United Kingdom	Extreme heatwave	2556	0
49	1998/5/26	India	Extreme heatwave	2541	0
50	1992/12/12	Indonesia	Earthquake	2500	1

Top 50 natural disasters worldwide by direct economic losses, 1991-2024

No.	Time	Affected countries/regions	Type of disaster	Direct economic losses (USD 0.1 billion, current year prices)	Fatalities (persons)
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	2021/8/28-9/2	The United States	Storm	651	96
8	2017/9/10-9/28	The United States	Storm	570	58
9	2024/9/25-9/28	The United States	Storm	560	219
10	2012/10/28	The United States	Storm	500	54
11	2023/2/6	Syria, Türkiye	Earthquake	429	56683
12	2021/7/12-7/15	Germany	Flood	417	242
13	2011/8/5-2012/1/4	Thailand	Flood	400	813
14	2024/10/9-10/10	The United States	Storm	380	32
15	1998/7/1-8/30	China	Flood	300	3656
16	2010/2/27	Chile	Earthquake	300	562
17	2021/2/10-2/20	The United States	Storm	300	235
18	2008/9/12-9/16	The United States	Storm	300	82
19	1994/1/17	The United States	Earthquake	300	60
20	2004/10/23	Japan	Earthquake	280	40
21	1992/8/24	The United States	Storm	265	44
22	2023/7/21-8/2	China, the Philippines	Storm	252.94	87
23	2019/10/10-10/17	The United States	Wildfire	250	3
24	2016/6/28-7/13	China	Flood	220	289
25	2008/1/10-2/5	China	Extreme coldwave	211	129
26	1999/8/17	Turkey	Earthquake	200	17127
27	2016/4/16	Japan	Earthquake	200	49
28	2012/6-2012/12	The United States	Drought	200	0
29	2010/5/29-8/31	China	Flood	180	1691
30	2004/9/15-9/16	The United States	Storm	180	52
31	2019/10/12-10/17	Japan	Storm	170	99
32	2020/5/21-7/30	China	Flood	170	280
33	2021/6/1-/8/30	China	Flood	165	352
34	2018/11/8-11/16	The United States	Wildfire	165	88
35	2014/9	India	Flood	160	298
36	2018/10/10-10/11	The United States	Storm	160	45
37	2005/9/23-10/1	The United States	Storm	160	10
38	2004/8/13	The United States	Storm	160	10
39	2012/5/20	Italy	Earthquake	158	7
40	2024/1/1	Japan	Earthquake	150	551
41	2011/2/22	New Zealand	Earthquake	150	181
42	1995/8/1-9/8	South Korea	Flood	150	68
43	2023/4/1-9/30	The United States	Drought	145	247
44	2005/10/24	The United States	Storm	143	4
45	1999/9/21	China	Earthquake	141	2264
46	2011/5/20-5/25	The United States	Storm	140	176
47	2018/9/12-9/18	The United States	Storm	140	53
48	1994/1-1994/12	China	Drought	138	0
49	2020/5/20	India	Storm	135	90
50	2020/8/27-8/28	The United States	Storm	130	33

Annex II Calculation Method, Data Source and Conversion Method for Comprehensive Disaster Index

01 Calculation method for comprehensive disaster index

The comprehensive disaster index has both temporal and spatial attributes, allowing for a quantitative assessment of the comprehensive disaster situation in a region in both temporal and spatial dimensions. The index is calculated based on multi-regional historical disaster data, which takes into account both time-series variability and inter-regional diversity. In this Report, the disaster index is mainly used to provide a quantitative assessment of China's overall disaster situation at the national and provincial levels. The national-level disaster index is used to evaluate the overall disaster situation of China by year, while the provincial-level disaster index is used to evaluate the overall disaster situation of each province by year. The calculation methods are briefly described below.

(I) Calculation method for national-level disaster index

1. Pretreatment of disaster indicators

The disaster indicators are divided into four dimensions of population, agriculture, housing, and economy. The population indicators include the population affected by disasters, the death and missing tolls, the population who have been urgently resettled, and the population in need of assistance due to drought and drinking water difficulties. The agricultural dimension indicators include the area of crops affected and the area of crops that have been lost. The housing dimension indicators include the number of collapsed houses and the number of damaged houses. The economic dimension indicator includes direct economic losses. Each disaster indicator in the three dimensions of population, agriculture and housing will be first normalized. The economic dimension indicator will be converted using the GDP index before normalization. The conversion method is detailed in Part II of the Appendix. The normalization formula is (take the affected population as an example)

$$P_a^* = \frac{P_a}{\max P_a}$$

In formula, P_a is the indicator of the affected population, $\max P_a$ is the maximum value of the indicator in the time series, and P_a^* is the normalized indicator.

2. Calculation of the dimension index

For each year in the historical series, the indicators of each dimension of China's overall disaster situation in that year are calculated separately, which is the geometric average of the normalized disaster indicators within the dimensions. The calculation formula is

$$I_P = (P_a^*)^{W_{pa}}(P_d^*)^{W_{pd}}(P_t^*)^{W_{pt}}(P_w^*)^{W_{pw}}$$

$$I_C = (C_a^*)^{W_{ca}}(C_d^*)^{W_{cd}}$$

$$I_H = (H_c^*)^{W_{hc}}(H_d^*)^{W_{hd}}$$

$$I_E = E^*$$

Refer to Attachment 1 and Attachment 2 for the meaning and weight of each symbol.

3. Calculation of the comprehensive disaster index

For a given year, the comprehensive disaster index (denoted as I) for that year is the geometric mean of the normalized indicators of its four dimensions. The formula is

$$I = (I_P^*)^{W_P}(I_C^*)^{W_C}(I_H^*)^{W_H}(I_E^*)^{W_E}$$

I_P^* , I_C^* , I_H^* , and I_E^* are the normalized values of I_P , I_C , I_H , and I_E respectively, and, W_P, W_C, W_H and W_E are the weight of the corresponding dimension indicator (Table 2).

Chi

Attachment 1 Disaster indicators and dimension indicator symbols for the calculation of national-level comprehensive disaster index

Dimension indicator	Symbol	Normalized symbol	Disaster indicator	Symbol	Normalized symbol
Dimension index of population	I_P	I_P^*	Affected population	P_a	P_a^*
			Death and missing tolls	P_d	P_d^*
			Evacuated population	P_t	P_t^*
			Number of people who need assistance due to drought and drinking water difficulties	P_w	P_w^*
Dimension index of agriculture	I_C	I_C^*	Area of affected crops	C_a	C_a^*
			Area of destroyed crops	C_d	C_d^*
Dimension index of housing	I_H	I_H^*	Number of collapsed dwellings	H_c	H_c^*
			Number of damaged dwellings	H_d	H_d^*
Dimension index of economy	I_E	I_E^*	Direct economic losses	E	E^*

Attachment 2 Weight symbols and assignments for the calculation of national-level comprehensive disaster index

Dimension index	Weight symbol	Weight assignment
Dimension index of population	W_P	0.30
Dimension index of agriculture	W_C	0.15
Dimension index of housing	W_H	0.30
Dimension index of economy	W_E	0.25
Dimension indicator	**Weight symbol**	**Weight assignment**
Affected population	W_{pa}	0.20
Death and missing toll	W_{pd}	0.40
Evacuated population	W_{pt}	0.20
Number of people who need assistance due to drought and drinking water difficulties	W_{pw}	0.20
Area of affected crops	W_{ca}	0.30
Area of destroyed crops	W_{cd}	0.70
Number of collapsed dwellings	W_{hc}	0.70
Number of damaged dwellings	W_{hd}	0.30

(II) Calculation method for provincial-level disaster index

The provincial-level disaster index is used to provide a quantitative assessment of the overall disaster situation of each year since 2000 in each province. A single assessment object is the overall disaster situation of a given year in a given province. The calculation process of the provincial-level disaster index is the same as that of the national-level disaster index. The differences between the steps are briefly described below.

1. Pretreatment of disaster indicators

Some provinces suffered no disaster in certain years with disaster indicator values at zero. In order to ensure that zero is not used in the geometric mean in the index calculation, the following formula is adopted for the normalization of the provincial disaster indicators (taking the affected population as an example).

$$P_a^* = 1 + \ln\left(1 + \frac{P_a}{\max P_a}\right)$$

2. Calculation of the dimension index

The formula for calculating the provincial agriculture, housing and economic dimension indicators is the same as that for the national level, and the calculation of the population dimension indicators does not include the population in need of assistance due to drought and drinking water difficulties. Specifically for

$$I_P = (P_a^*)^{W_{pa}}(P_d^*)^{W_{pd}}(P_t^*)^{W_{pt}}$$

3. Calculation of the comprehensive disaster index

The formula for calculating the provincial-level comprehensive disaster index is

$$I = (I_P^*)^{W_P}(I_C^*)^{W_C}(I_H^*)^{W_H}(I_E^*)^{W_E} - 1$$

The meaning of each symbol and the normalization method of each dimension indicator in the calculation of the provincial-level disaster index are the same as those of the national-level disaster index. Except for the population dimension indicators, the weight values of the other dimension indicators and disaster indicators are also the same as those for the national-level disaster index. Attachment 3 shows the calculation of the weight assignment of the population dimension.

Attachment 3 Calculation of the weight assignment of the population dimension for the provincial-level comprehensive disaster index

Dimension indicator	Weight symbol	Weight assignment
Affected population	W_{pa}	0.25
Death and missing tolls	W_{pd}	0.50
Evacuated population	W_{pt}	0.25

02 Data sources and conversion methods

1. Data on China's total population, gross domestic product (GDP) and provincial permanent population and gross regional product (GRP) at the end of the year from 2004 to 2023 are from the annual data of the National Bureau of Statistics.

2. Data on China's total population and GDP at the end of 2024 are sourced from the Statistical Communiqué of the People's Republic of China on the 2024 National Economic and Social Development released by the National Bureau of Statistics.

3. The permanent resident population of each province (autonomous region and municipality directly under the central government) at the end of 2024 is estimated using the natural growth rate of Chinese population in 2024 published by the National Bureau of Statistics:

Permanent resident population at the end of 2024 = permanent resident population at the end of 2023× (1-1.48‰)

The GRP of each province (autonomous region and municipality directly under the central government) in 2024 is estimated using the GDP growth rate in 2024 published by the National Bureau of Statistics:

GRP in 2024 = GDP in 2023 × (1+5.2%)

4. Conversion methods for GDP and direct economic losses.

In the Report, the GDP from 2004 to 2024 and the direct economic losses caused by disasters in China are converted according to the GDP index published by the National Bureau of Statistics, with 2004 as the base period, and the calculation formula is:

Converted value of GDP for the year = GDP for 2004 × cumulative value of the GDP index for that year relative to 2004

The rate of change in GDP in that year compared to 2004 = GDP in that year ÷ converted value of GDP in that year

Converted value of direct economic losses for the year = direct economic losses for the year ÷ rate of change in GDP for that year compared to 2004

In the formula, "cumulative value of the GDP index for the year relative to 2004" is the product of the GDP index (1 denotes the previous year) from 2004 to the current year, and the year 2004 is expressed as 1. In the case of 2010, the cumulative value is the product of the GDP index from 2004 to 2010 (1 denotes the previous year).

From 2004 to 2024, the GRP of each province and the direct economic losses of each disaster type in each province are converted using the above method, and the GDP index is replaced by the GRP index of the province.

Annex III Assessment Methods for Indirect Economic Impacts

The economic impact of disasters encompasses direct losses and indirect effects, including their ripple effects. In an era of regional and global economic integration, assessing the indirect economic impacts of natural disasters or climate change requires a broader perspective. Such assessments must account for not only losses within the disaster zone itself—including production reductions from local supply chain disruptions—but also ripple effects beyond it, such as production shortfalls caused by broken inter-regional industrial linkages[12,13].

Currently, the assessment methods for the indirect economic impacts of disasters can be roughly divided into three categories based on their development status[14]. First, econometric models typically establish a quantitative relationship between the intensity of disaster shocks and macroeconomic performance through statistical methods, reflecting historical trends and progress in the economy yet failing to respond reasonably to the impacts caused by disasters. Second, input-output (IO) models focus on reflecting the cascading losses from disruptions in industrial linkages, and can dynamically assess the losses during the recovery process until returning to pre-disaster levels. Third, computable general equilibrium (CGE) models emphasize long-term macroeconomic impacts (GDP, employment, price fluctuations) and highlight the importance of price factors and markets.

The indirect economic impact assessment model used in this study is based on the Adaptive Regional Input-Output (ARIO) model and the Adaptive Regional Input-Output Inventory (ARIO-Inventory) model, considering the Adaptive Multi-regional Input-Output with Inventory and Labor (AMIL) model. The ARIO model fully considers the changes in production capacity of sectors after a disaster, changes in production bottlenecks, and production constraints caused by production reductions and industrial linkages. It has been applied to the assessment of indirect losses from Hurricane Katrina in the United States in 2005, with results showing that the indirect economic losses from Hurricane Katrina were as high as 1.4 times the direct losses, exceeding USD 140 billion[15]. The AMIL model further considers the economic impacts of reduced labor supply after a disaster, recovery, and the introduction of labor from outside the region, as well as the spillover effects on the economy outside the disaster area due to the economic damage in the disaster area through industrial linkages. It has been applied to the assessment of indirect economic impacts caused by heavy rain and flooding in Wuhan in 2016. According to this model, the reduction in labor supply due to the disaster caused Wuhan to lose an additional 15.12%, while the indirect economic impact on unaffected areas was CNY 2.429 billion, which is 4.38 times higher than that of Wuhan[16].

[12] Li J, Crawford-Brown D, Syddall M, et al. 2013. Modeling imbalanced economic recovery following a natural disaster using input-output analysis. Risk Analysis, 33(10): 1908-1923.
[13] Bäumen H S I D, Többen J, Lenzen M. 2015. Labour forced impacts and production losses due to the 2013 flood in Germany. Journal of Hydrology, 527: 142-150.
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The AMIL model comprises four main modules: an adaptive dynamic iteration module (A), a multi-regional economic spillover effect module (M), an inventory heterogeneity module (I), and a labor loss and recovery module (L). The AMIL model emphasizes the recovery of labor during the economic recovery process after a disaster, the ripple effects on the economy outside the disaster area, and the differential effects of inventory shortages. Its theoretical framework is illustrated in the following figure:

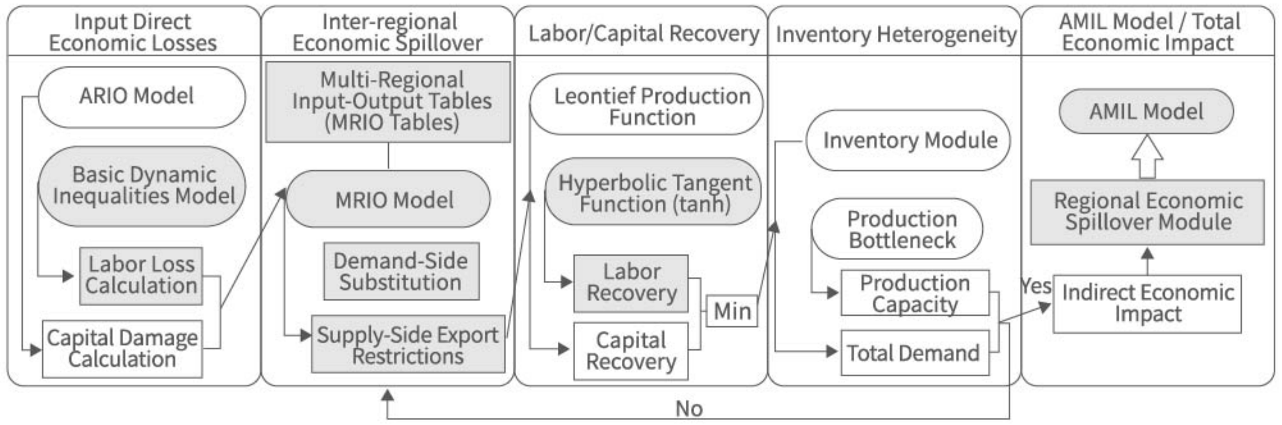

Figure 1 Overview of the theoretical framework of the AMIL model
(The grey part refers to the new sections added compared to ARIO and ARIO-Inventory.)

First, the direct economic losses are introduced into the model, which includes the labor loss component in the "L" module. Furthermore, external adaptive behaviors such as government and insurance company assistance are considered, introducing the "M" multi-regional economic spillover effect module. The third stage involves introducing the labor recovery component in the "L" module; based on the principles of resilience and disaster impact mechanisms on the population, this component incorporates different labor recovery functions to assess corresponding scenarios. The fourth stage considers production bottlenecks, introducing the "I" inventory heterogeneity module, which will be based on the inventory settings in the ARIO-Inventory model, combined with the impact of the labor module on inventory and the effects of inventory shortages on inter-regional spillover effects for targeted optimization. The fifth stage involves continuous iteration through the above calculations and comparisons until supply and demand are balanced, ultimately calculating the indirect economic impact value within the disaster area and the economic spillover value outside the disaster area.

The data required for model application calculations includes: direct economic losses, disaster-affected population data, fixed asset stock data, and multi-regional input-output tables. The loss data and disaster data are primarily based on announcements and reports released by the government and official sources, the fixed asset stock data is mainly derived from urban statistical yearbook data, and the input-output data references the 2017 urban multi-regional input-output table from the Carbon Emission Accounts and Datasets (CEADs) and relevant data from the Global Trade Analysis Project (GTAP).

[15] Hallegatte S. 2008. An adaptive regional input-output model and its application to the assessment of the economic cost of Katrina. Risk Analysis, 28(3): 779-799.
[16] Zhang Z, Li N, Cui P, Xu H, Liu Y, Chen X, Feng J. 2019. How to integrate labor disruption into an economic impact evaluation model for Postdisaster recovery periods. Risk Anal. 39 (11), 2443–2456. https://doi.org/10.1111/risa.13365.

Annex IV 65 Industry Codes and Names

Industry Code	Industry	Industry Code	Industry
S1	Rice Planting	S18	Other Mining
S2	Wheat Planting	S19	Beef, Mutton, and Horse Meat Processing
S3	Other Grain Cultivation	S20	Other Meat Processing
S4	Fruit, Nut, and Vegetable Cultivation	S21	Vegetable Oil and Fat Manufacturing
S5	Oilseed Crop Cultivation	S22	Dairy Product Manufacturing
S6	Sugar Crop Cultivation	S23	Rice Processing
S7	Fiber Crop Cultivation	S24	Other Food Manufacturing
S8	Other Crop Cultivation	S25	Beverages and Tobacco Products
S9	Cattle, Sheep, Horse, and Other Livestock Rearing	S26	Textiles
S10	Other Animal-Derived Products	S27	Sugar
S11	Fresh Milk Production	S28	Apparel and Clothing
S12	Wool and Silkworm Cocoon Production	S29	Leather Products Industry
S13	Forestry	S30	Wood Processing Industry
S14	Fisheries	S31	Pulp and Paper Products and Printing Industry
S15	Coal Mining	S32	Petroleum and Coal Processing
S16	Crude Oil Extraction	S33	Pharmaceutical Manufacturing
S17	Natural Gas Extraction	S34	Chemical Raw Materials and Products

Industry Code	Industry	Industry Code	Industry
S35	Rubber and Plastic Products Manufacturing	S50	Wholesale and Retail Trade
S36	Other Non-metallic Mineral Products	S51	Accommodation and Catering Services
S37	Ferrous Metal Smelting	S52	Other Transportation
S38	Smelting of Other Metals	S53	Water Transportation
S39	Metal Products Manufacturing	S54	Aviation Transportation
S40	Computer, Electronic, and Optical Equipment Manufacturing	S55	Warehousing and Auxiliary Activities
S41	Electrical Machinery Manufacturing	S56	Telecommunications
S42	Other Specialized Equipment Manufacturing	S57	Other Financial Activities
S43	Automobile and Auto Parts Manufacturing	S58	Insurance
S44	Other Transportation Equipment Manufacturing	S59	Real Estate
S45	Other Manufacturing Industries	S60	Other Business Services
S46	Electric Power Production and Supply	S61	Culture, Entertainment, and Other Services
S47	Gas Production and Supply	S62	Public Administration and Social Security
S48	Water Production and Supply	S63	Education
S49	Construction	S64	Health and Social Work
		S65	Self-owned Housing Services

Declaimer

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