TIEMS 2021 Virtual Annual Conference

New characteristics of flood risk and emergency capacity strengthening under changing environment

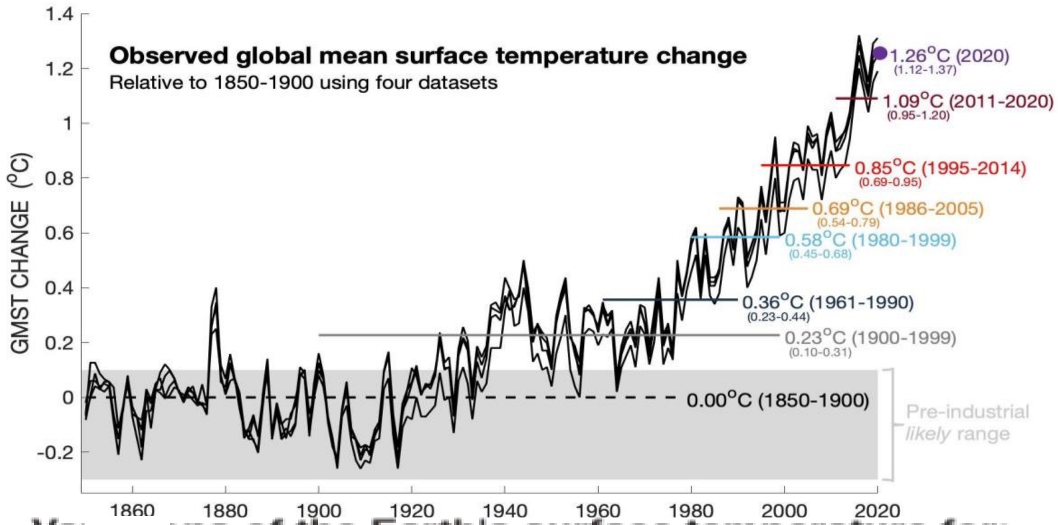
CHENG Xiaotao

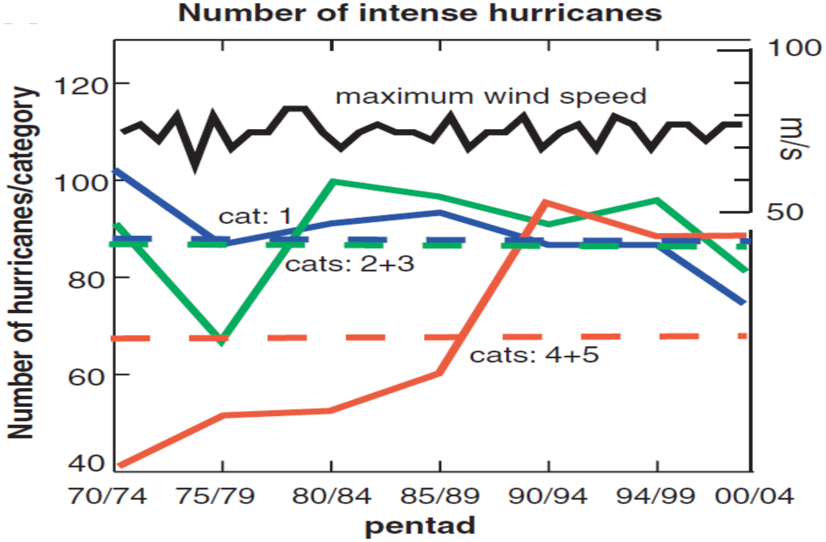
China Institute of Water Resources and Hydropower Research (IWHR)

December 6, 2021

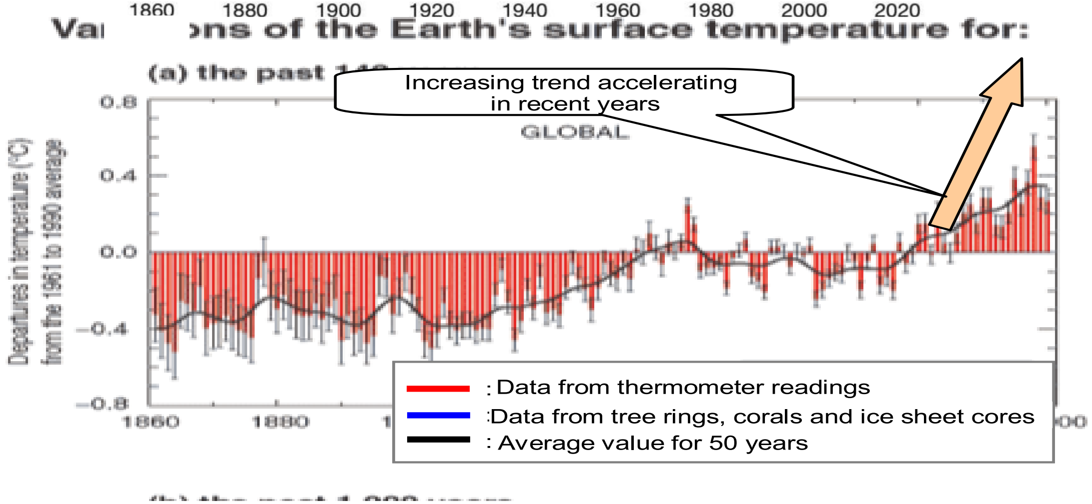
For the changing environment on flood risk characteristics, the effects of global warming cannot be ignored

Global warming increases the probability of extreme weather events, and the established flood control system and emergency response system have to face greater pressure and challenges.





Source: Webster et al, Science 309, 2005



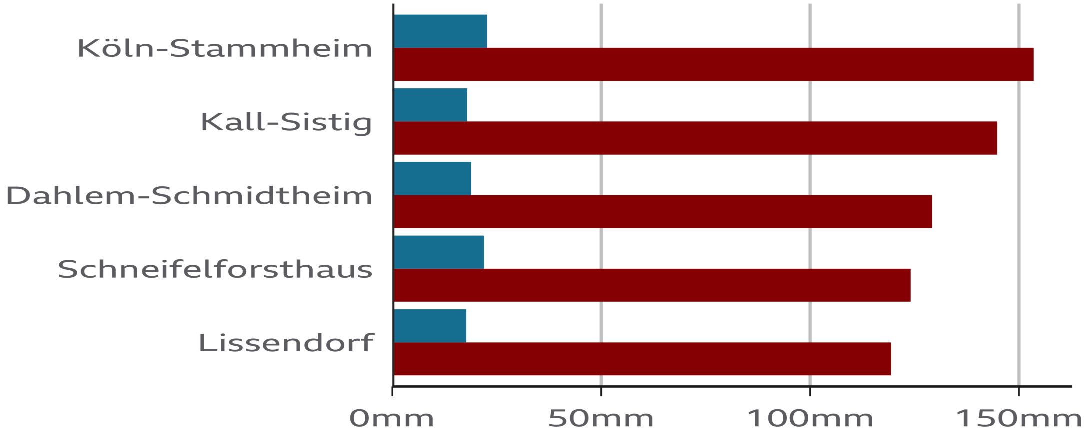
Excerpts from "Climactic Change 2001", a Report of the First Working Group in the Third Evaluation Report of the IPCC

Unusually heavy rains hit Western Europe in July 2021

- More than 182mm (7.2ins) fell in 72 hours in some areas of Germany, Belgium, Luxembourg, the Netherlands, Switzerland and other countries between July 12 and 15. Among the worst-hit parts of Germany, the area of the city of Cologne as Köln-Stammheim saw more than 153mm of rain on 14 July, it is six times higher than the average heaviest rainfall days for the area in July. More than 229 fatalities and 30 bln euros damage caused by dike breach and flooding.

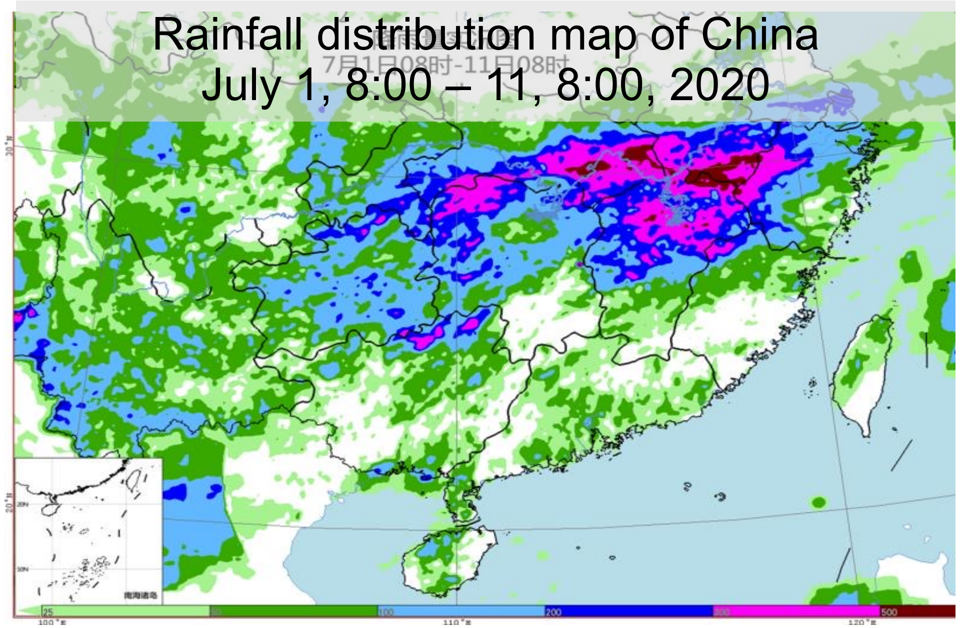
Worst-hit areas saw rainfall levels far above average high for July

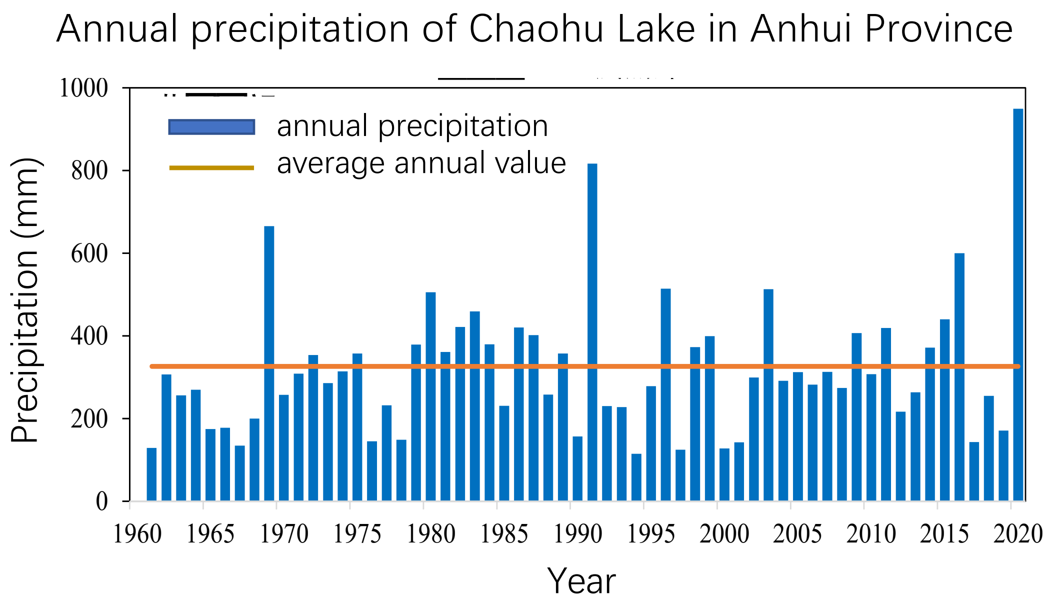
30-year average high and **14 July 2021** compared

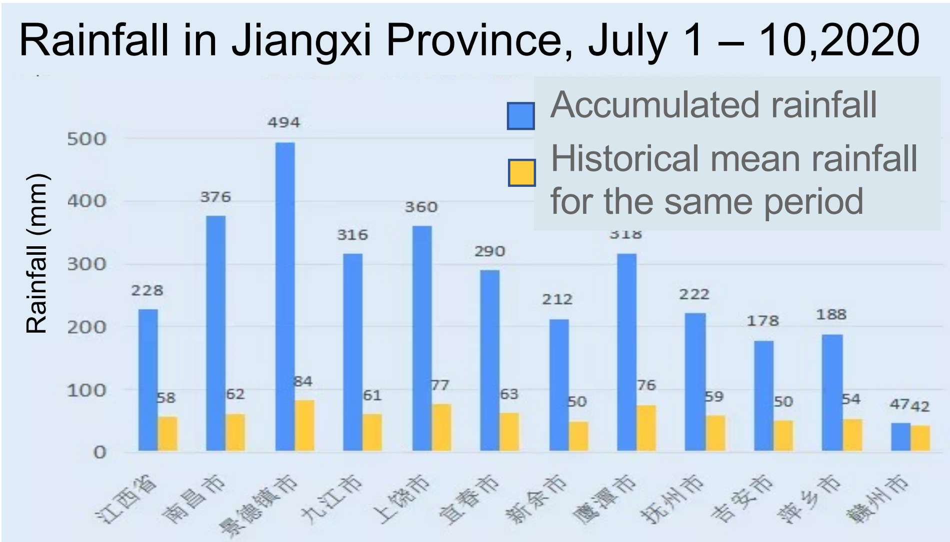


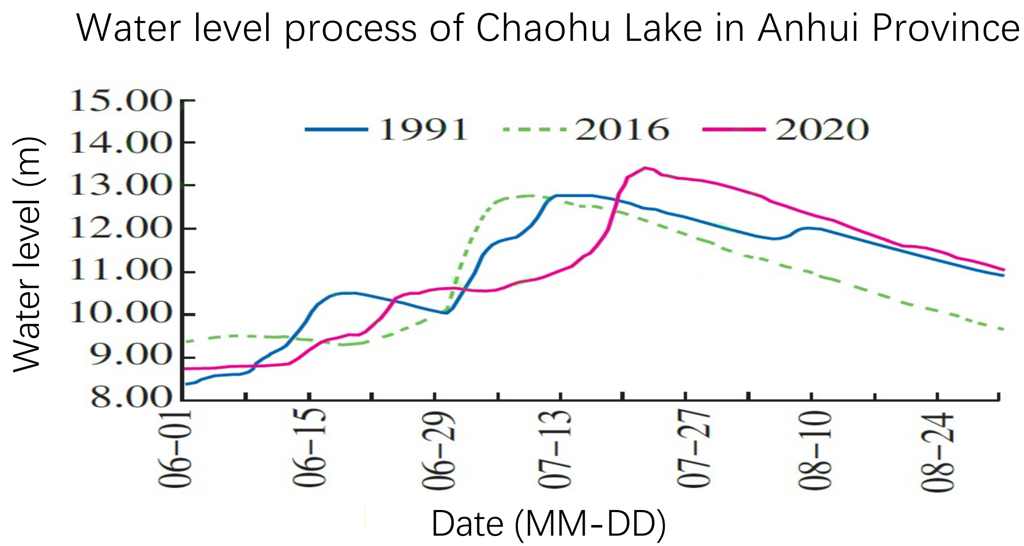
Source: German Weather Service (DWD)

Source: Copernicus EMS Rapid Mapping Service 16 July


Rainfall distribution map of China
July 1, 8:00 – 11, 8:00, 2020
7月1日08时-11日08时

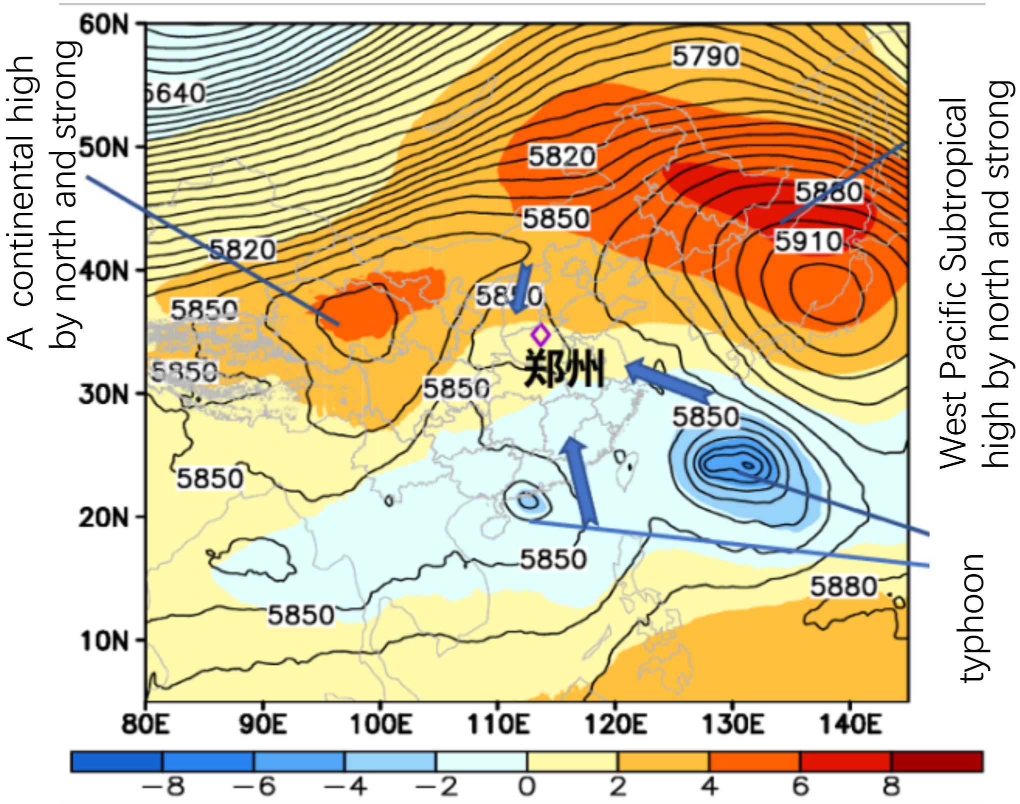

Annual precipitation of Chaohu Lake in Anhui Province
annual precipitation
average annual value
Precipitation (mm)
0
200
400
600
800
1000
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Rainfall in Jiangxi Province, July 1 – 10,2020
Accumulated rainfall
Historical mean rainfall for the same period
Rainfall (mm)
0
100
200
300
400
500
228
58
376
62
494
84
316
61
360
77
290
63
212
50
318
76
222
59
178
50
188
54
47
42
江西省
南昌市
景德镇市
九江市
上饶市
宜春市
新余市
鹰潭市
抚州市
吉安市
萍乡市
赣州市

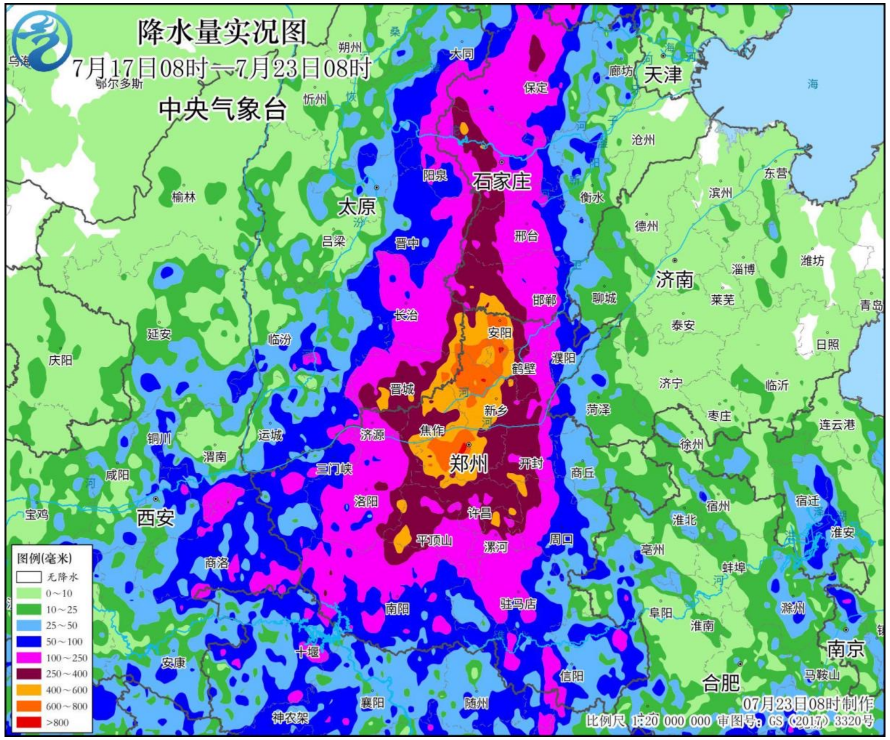

Water level process of Chaohu Lake in Anhui Province
1991
2016
2020
Water level (m)
8.00
9.00
10.00
11.00
12.00
13.00
14.00
15.00
06–01
06–15
06–29
07–13
07–27
08–10
08–24
Date (MM-DD)

Abnormal weather system affecting China in July 2021

The daily rainfall of 20 meteorological stations in Zhengzhou, Xinxiang, Hebi and Anyang exceeded the historical maximum. The max. daily rainfall of Zhengzhou station is 624.1mm, which is close to the annual rainfall of 641mm and 3.3 times of the max. daily rainfall in the past.



Source: https://mp.weixin.qq.com/s/k3G683OZtaHoM2X2BCcVeQ

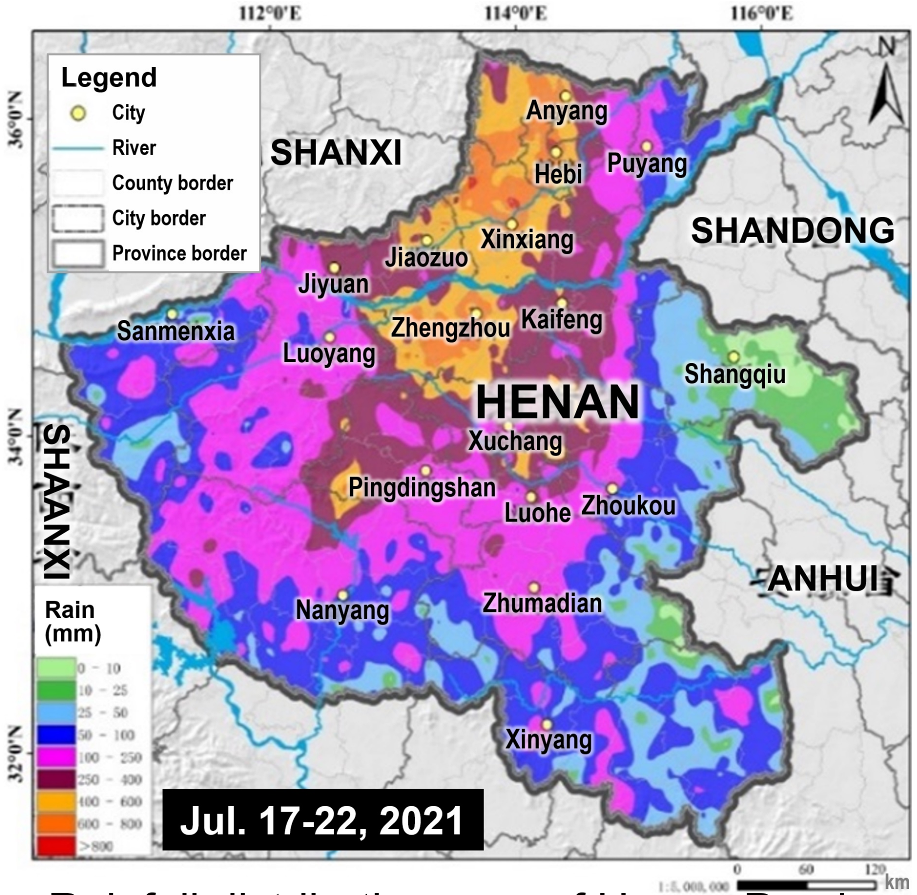


Precipitation from July 17-8:00 to 23-8:00, 2021

Basic characteristics of "21.7" extreme rainstorm flood in Henan, China in 2021

- Rainfall over 400mm, 250mm and 100mm poured down onto areas of 18,300 km^2, 46,300 km^2 and 96,200 km^2, respectively.
- Continuous heavy rains caused widespread flooding in rivers in Henan. A total of more than ten rivers in the province were flooded over the warning level. Among them, some sections of the Jialu, Dasha, Anyang, Gongqu, and Weihe rivers experienced the highest level of flooding in history .

River name	Station name	Max. flow (m^3/s)	Highest water level (m)	Max. flow in history (m^3/s)	Highest level in history (m)
Jialu	Zhongmou	600	79.40	245	77.69
Weihe	Jixian	265	72.76	260	70.77
	Qimen	460	68.03	824	67.45
Dasha	Xiuwu	343	83.65	203	83.02
Gongqu	Hehe	1,320	76.77	1,710	75.90
	Huangtugang	1,140	73.67	1,290	71.48
Anyang	Henshui	607	6.94	1,140	6.8

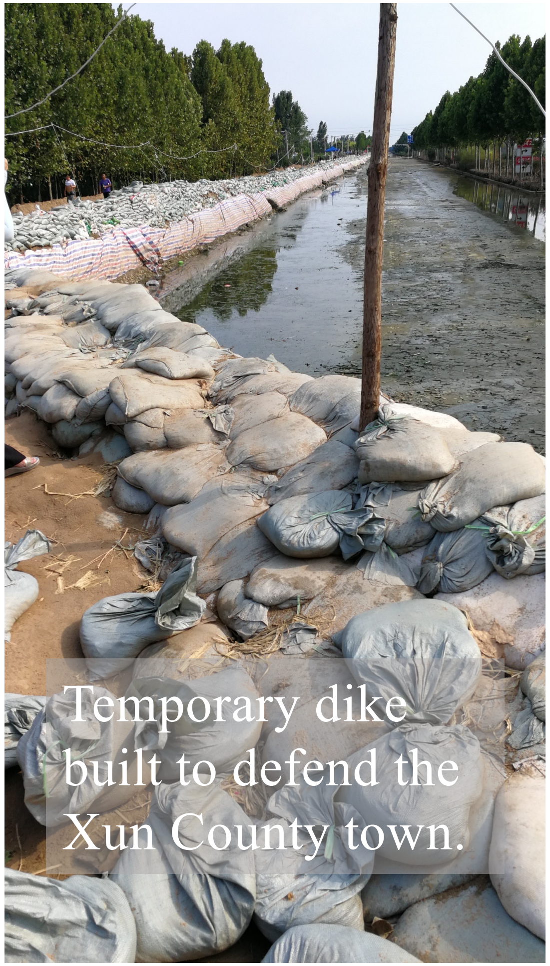


Rainfall distribution map of Henan Province

July 17, 8:00 – 23,8:00, 2021

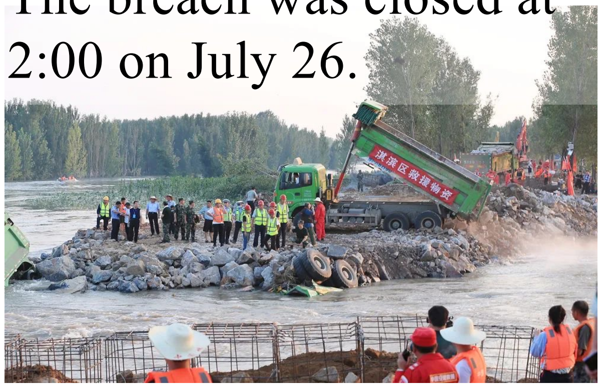
The maximum rainfall in Xinxiang was 267.4mm in two hours and 812.0mm in 48 hours, both exceeding the record in Zhengzhou (262.5mm, 807.6mm).

Flood fighting, a severe test



Temporary dike built to defend the Xun County town.

July 22, 17:00, Weihe River left dike burst at Peng village, Xun County. The breach was closed at 2:00 on July 26.

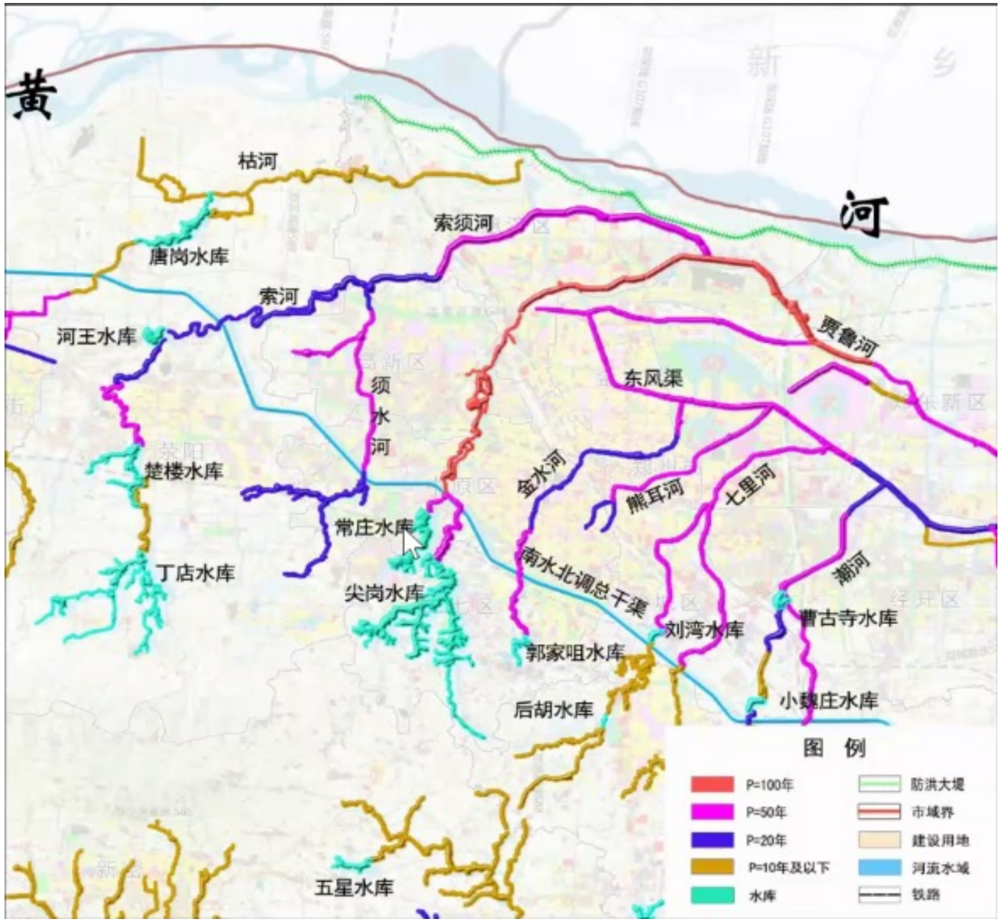


On July 24, a breach appeared in the Gongqu canal near Muye bridge in Weihui city

At 9:00 on July 26, the 100m breach was successfully closed

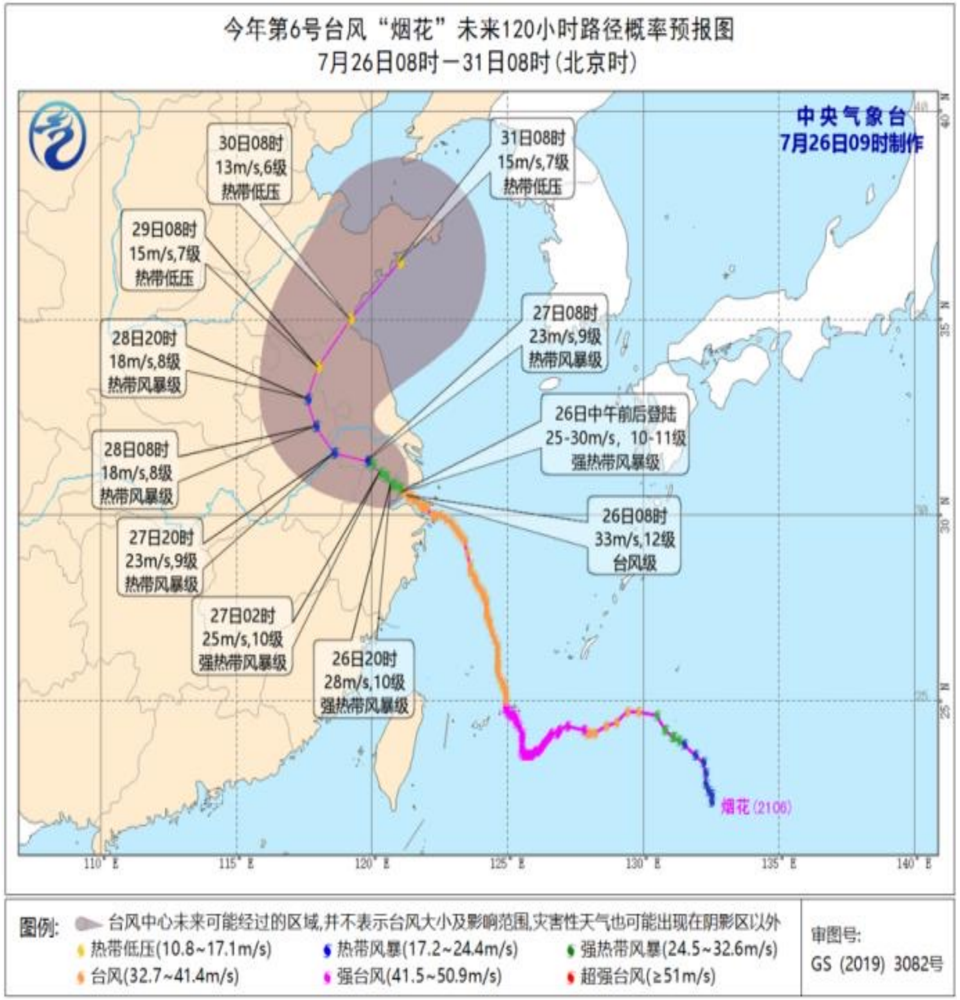
Pressure and difficulty of reservoir operation

- As of 8:00 on July 23, 2021, the total amount of water stored in 24 large reservoirs and 102 medium-sized reservoirs in Henan province reached 5.74 billion m^3 and 1.23 billion m^3 respectively, 2.56 billion m^3 and 497 million m^3 more than the annual average of the same period (3.82 billion m^3, 733 million m^3).
- Among them, the highest water level of 14 reservoirs, including Panshitou, Xiaonanhai, Jiangang, Wuxing, etc., exceeded the all-time high since the reservoirs were built.
- The maximum inflow flow of Changzhuang and Jiangang reservoir in the upper reaches of Jialu River were 905m^3/s and 1,090m^3/s, and the outflow were 564m^3/s and 64 m^3/s, respectively.



Adverse effects of Typhoon In-Fa

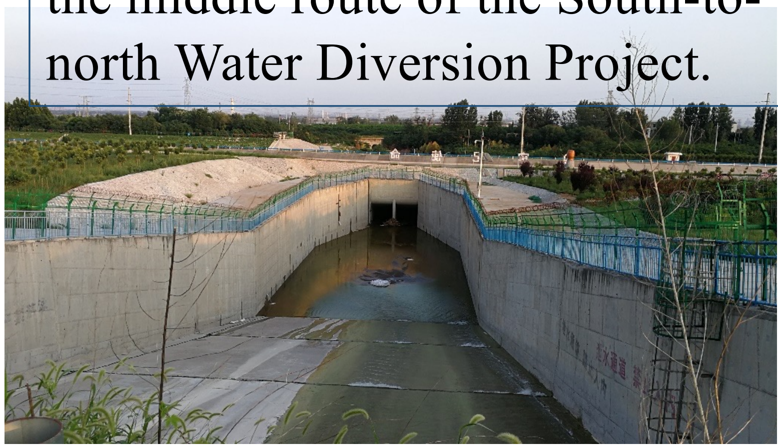
- However, the Typhoon In-Fa landed in Zhejiang on July 25. In order to face a new round of heavy rain, all dams have to be required to reduce the reservoir water level below the flood limit level, that increased the flood fighting pressure in the middle and lower reaches of rivers involved.
- From July 21 to 30, eight out of the nine flood storage and detention areas in the Weihe River basin were successively put into use, with a maximum flood storage capacity of 859 million m^3, effectively lowering the water level of the Weihe River and its tributaries.



Serious damage caused by flash floods

Xinxiang Luwangfen township accumulated rainfall of 970 mm, roads washed away by flash floods.

Flash floods threatened the safety of the main canal of the middle route of the South-to-north Water Diversion Project.



House destroyed by flash flood

Agriculture suffered heavy losses

Flooded enterprises faced the dilemma of capital chain and industrial chain interruption.

Flood garbage disposal becomes a big problem in flooded cities

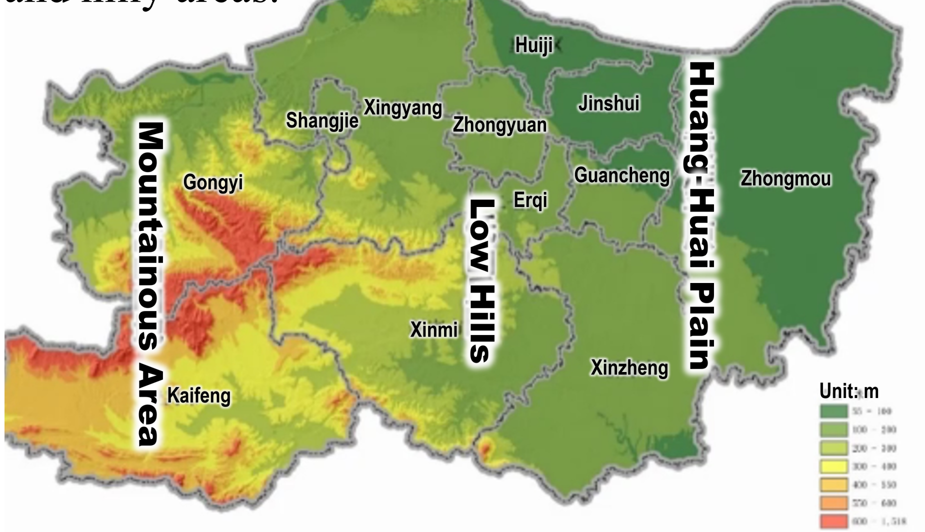
Evolution characteristics of flood risk under changing environment

- The “21.7” extraordinary rainstorm and flood disaster in Henan province, on the one hand, reflects the disrupted weather system associated with global warming, which is more likely to cause extreme flood events. On the other hand, it also reflects the impact of rapid economic development and urbanization on flood risk characteristics.
- When the super heavy rain fell on a huge and rapidly expanding city with a population of more than ten million, its threat object, disaster mechanism, disaster mode and loss composition changed dramatically, and flood risk presents the characteristics of linkage, mutation and transmissibility.

Due to the increasing dependence of the normal operation of modern society on transportation, communication, power supply, water supply and other lifeline network systems, and closer and wider industrial chains formed with economic development, in the event of excessive flooding, the chain reaction within and between the affected systems causes a sudden increase in disaster losses, and its influence range can be transmitted far beyond the flooded area along with the lifeline system and the industrial chain.

Effects of rapid urbanization

- By 2020, the permanent resident population of Zhengzhou had reached 12.6 million, increasing by 3.97 million just in 10 years. Its total urbanized area had increased by 702 km^2, and the area of water and wetland decreased by about 30%.
- With the expansion of the urban area, some flood channels outside the city have become the city's internal rivers, that increases the risk of flash flood entering the city from the southwest mountainous and hilly areas.



- Zhengzhou covers an area of 7,567km^2, is located on the south bank of the Yellow River and straddles the Yellow River and Huaihe River basins, with 27% and 73% respectively of Zhengzhou being in these two basins. It straddles Songshan Mountain, low mountains and hills and Huang-Huai Plain, with the overall terrain higher in the west and lower in the east. Plains, hills and mountains account for about 70%, 24.9% and 4.7% respectively

Post-disaster reconstruction were adversely affected by epidemic prevention

- After the huge flood disaster, Zhengzhou faced a very difficult task of disaster relief and reconstruction.
- Unfortunately, a nucleic acid positive case was found in Zhengzhou on July 30, and further, 12 local cases and 20 asymptomatic cases were detected on July 31. One high-risk residential district and three medium-risk residential districts were forced into lockdown, and access to and from Zhengzhou was also strictly controlled, that undoubtedly created a greater obstacle to post-disaster reconstruction.
- With the efficient organization by governments at all levels and the great support from all over the country, power supply had been basically restored for 1,194 residential areas by July 30; water supply completely restored in 1,864 residential areas by August 1; and gas supply restored in 111 residential areas by August 2. All five subway lines in the city resumed their operation in two phases on September 12 and 15.

The recovery of Zhengzhou after the disaster， Sept. 21

Evolution characteristics and trend of flood risk

	Traditional society	Modern society
Threatened objects	Households, livestock, farmland, villages, towns, roads and water infrastructure in the flooded area (A)	(A)+Power, water, gas and oil supply, communication, network and other lifeline network systems, motor vehicles, etc.; The scope of impact far beyond the flooded area;
Disaster-causing mechanism	Disaster mainly caused by external natural force (B). The loss is directly proportional to the water depth, velocity and flooded duration	(B)+Disaster-causing forces are artificially amplified or weakened; Exposure and vulnerability of the disaster-bearing body are the main reasons for the aggravation or alleviation of the disaster. Water pollution exacerbates the flooding.
Disaster-forming pattern	Loss of human and animal life, loss of assets, destruction of infrastructure by flooding (C), and subsequent plague and famine.	(C)+Once the scale of flood exceeds the disaster prevention capacity, the affected area expands rapidly, and the flood loss rises sharply; The severity of the disaster is related to the speed of recovery and the way of loss sharing.
Components of losses	Mainly direct economic losses, such as casualties, loss of crops, damage of houses and property, etc. （D）	（D）+ The proportion of indirect loss caused by secondary and derivative disasters increased greatly because of the ripple effect of a damaged lifeline system and disruption of industrial chain.
Features of flood risk	The greater the scale of flood, the greater the possible loss; The high-risk area of flood and its consequences can be roughly judged by experience.	The spatial and temporal distribution of risks and the uncertainty of possible consequences increased greatly. The exposure and vulnerability of the disaster bearing body have become important aspects to be considered to restrain the increase of flood risk.

Discussion on countermeasures against extreme flood under the new situation

- In recent years, extreme disaster events have occurred frequently, and uncertainty has increased, which warns us that the trend of flood risks in the context of climate warming and rapid urbanization should be recognized and that we should coordinate development and security, improve risk prevention and emergency response system, and strengthen the resilience of urban centers and other residential areas to adapt to and withstand catastrophes.
- After the occurrence of the "21.7" huge flood disaster in Henan province, widespread concern was expressed about how to prevent and deal with extreme rainstorm flood. Discussions began in some cities, such as Beijing, Wuhan, Fuzhou, Shenzhen and Kunming, on what kind of disaster scenario would occur if the heavy rain of 201.9 mm per hour in Zhengzhou fell on their head, and actions were proposed for risk prevention and emergency response,

Risk identification	Enhance the ability to identify disaster types and their high-risk areas/hotspots, considering the most likely and most adverse event scenarios, and identify potential victims and their vulnerability and correlation. Take necessary preventive measures.
Danger perception	Improve the monitoring, forecast and early warning systems, and clarify the scope, objects and effective delivery of graded early warning information; Be familiar with the precursors of different levels of danger, and strengthen the training and exercise of rapid and comprehensive judgment on multi-source information.
Flood fighting	Improve the ability to quickly distinguish the categories, grades and urgency of dangerous situations. Rely on the water conservancy engineering system and natural geographical conditions for flood detention, peak cutting and energy dissipation, and control the flood damage to the tolerable limit.
Emergency response	Strengthen the ability of emergency response, specify in the plan the scope of transfer, resettlement methods and objects in need of assistance for different scales of danger, organize drills for self-protection and mutual rescue; Ensure the operation and quick repair of lifeline systems.
Damage endurance	Take preventive measures to mitigate risks and reduce losses; and reduce risks to tolerable limits as far as possible; Adopt a way of production, operation and life conducive to risk diversification; To share risks in time and space by insurance mechanism or means.
Resilience reconstruction	Comprehensively analyze the causes of the disaster, weak links and weaknesses in disaster prevention system, draw lessons in the reconstruction, and explore feasible improvement measures that can help improve the resilience of the system; Set priorities the disaster, and take a holistic approach, and avoid blindly transferring risks.

Thank you for your attention!

QR Code of the Journal of Hydraulic Engineering, CHES, IWHR & CHINCOLD