China Flash Flood Early Warning Systems

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Research Center on Flood & Drought Disaster Prevention and Reduction (CDPR)

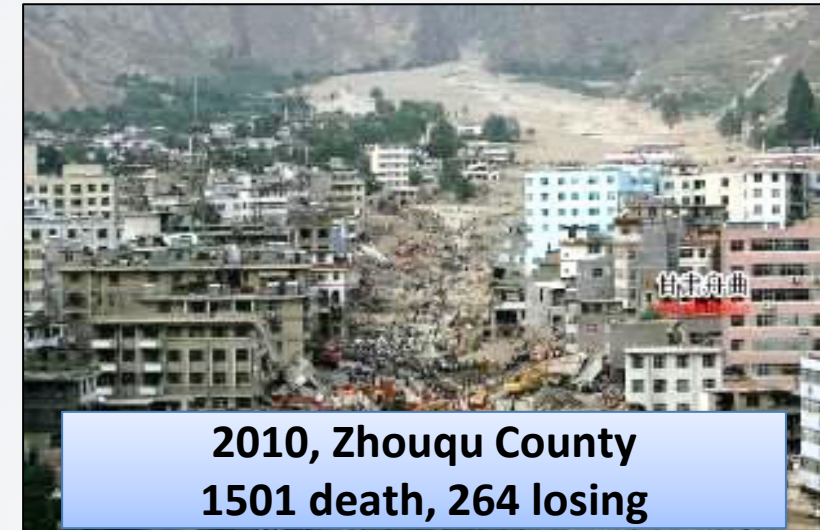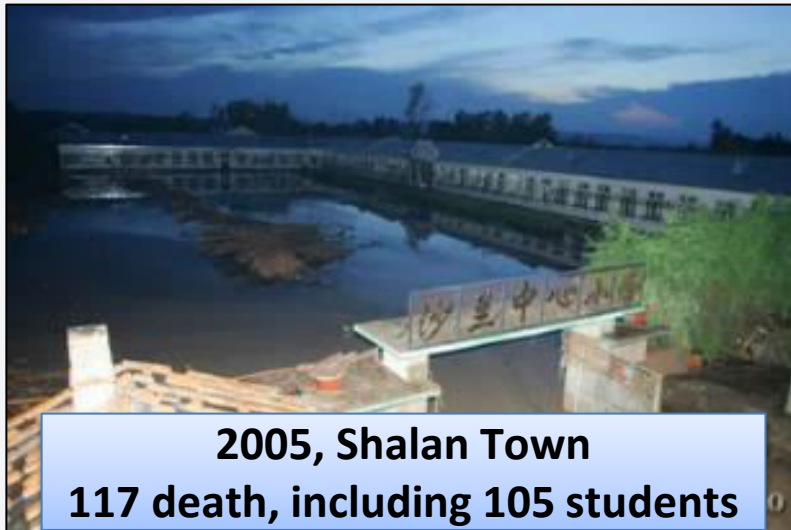China Institute of Water Resources and Hydropower Research (IWHR)

IWHR   CDPR

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International Water Resources Association (IWRA)

XVIII WORLD WATER CONGRESS
Water for All
Harmony between Humans and Nature

第18届
世界水资源大会
水与万物：
人与自然和谐共生

Content

2005, Shalan Town
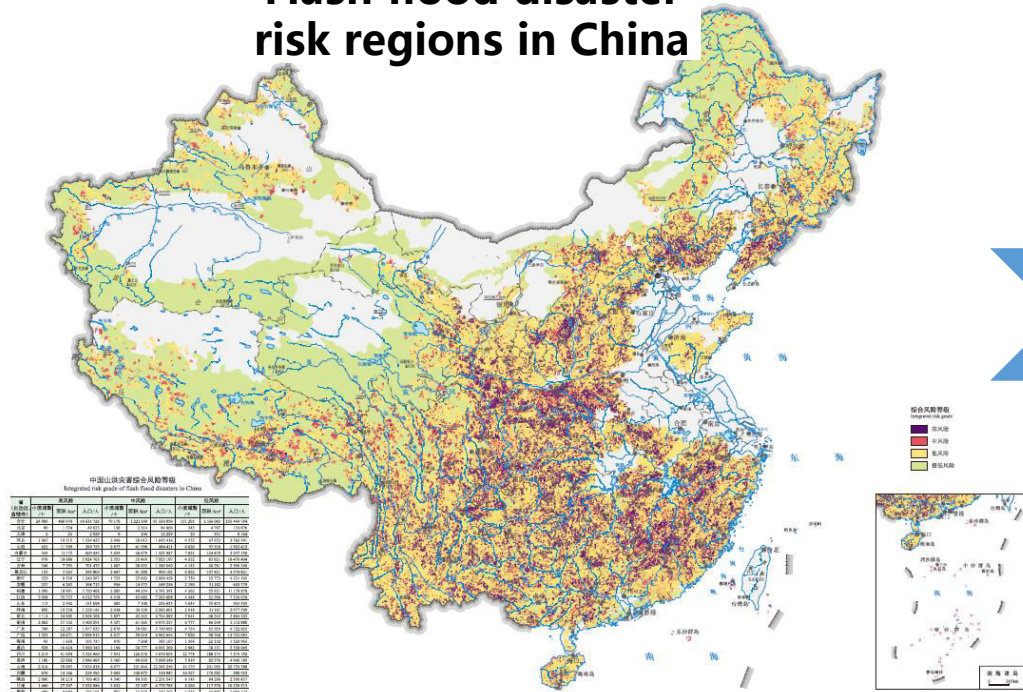117 death, including 105 students

2005, Hunan Prov.
346 death, 89 losing

2010, Zhouqu County
1501 death, 264 losing

2021, Zezhou County
5 death, 4 losing

2021, Zhengzhou City
82 death, 42 losing (flash flood)

2021, Liulin Town
24 death

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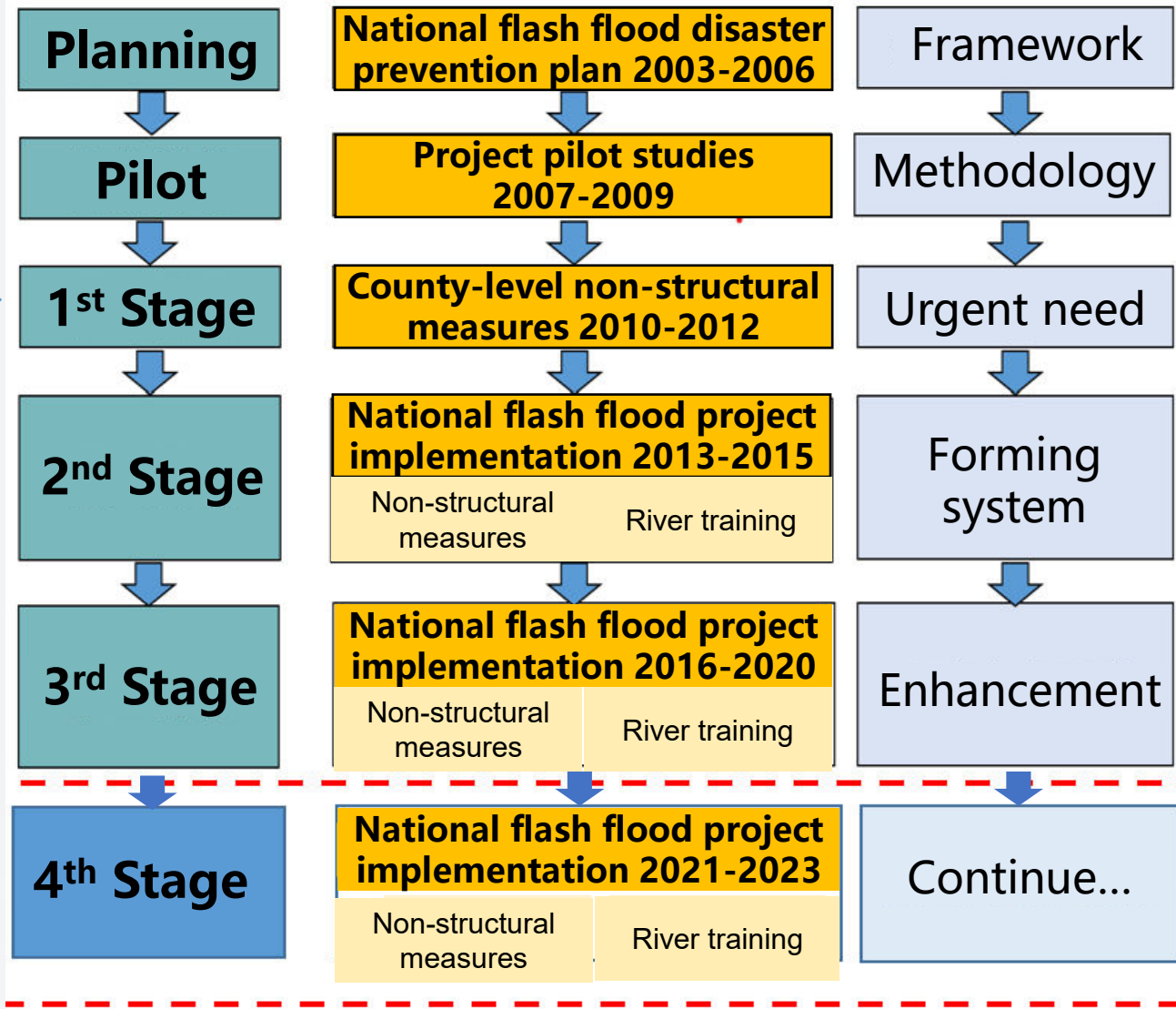
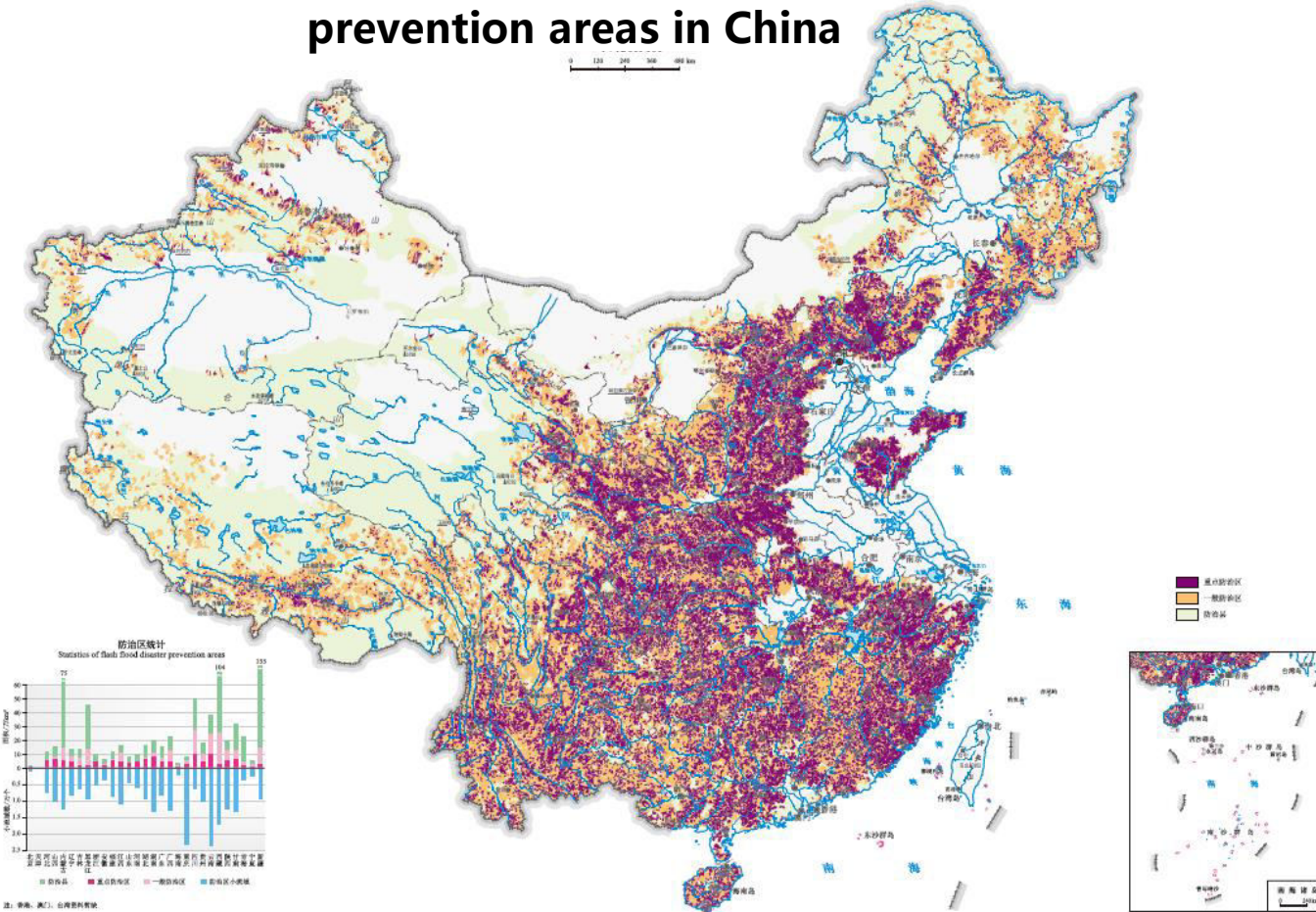**Flash flood disaster risk regions in China**

Charact-eristics of Flash Flood in China	Densely distributed in all mountain areas.
	Frequently happened with many disastrous events within definite season and region.
	Happened in very short time with catastrophic results.
	Casualties take 70% of that caused by all flood disasters.
	Extremely difficult to forecast and prevent.

Planning

Pilot

1st Stage

2nd Stage

3rd Stage

4th Stage

National flash flood disaster prevention plan 2003-2006

Project pilot studies 2007-2009

County-level non-structural measures 2010-2012

National flash flood project implementation 2013-2015

| Non-structural measures | River training |

National flash flood project implementation 2016-2020

| Non-structural measures | River training |

National flash flood project implementation 2021-2023

| Non-structural measures | River training |

Framework

Methodology

Urgent need

Forming system

Enhancement

Continue…

2010-2023, Project Contents and Investments

Flash flood disaster prevention areas in China

Project Contents	Ratio (%)
Investigation and assessment	13
Monitoring	15
Warning system	14
Monitoring & warning platform	20
Community-based system	11
Emergency rescuing	1
Structural measure	15
Others	10
Total	100

Total investment 42 billion CNY

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Flash flood disaster prevention big database established

全国山洪灾害防治区分布图

全国山洪灾害危险区分布图

- **Villages with risk: 1.57 million**

- **Spatial objects: 45.76 million**

- **Assessed villages: 170,000**

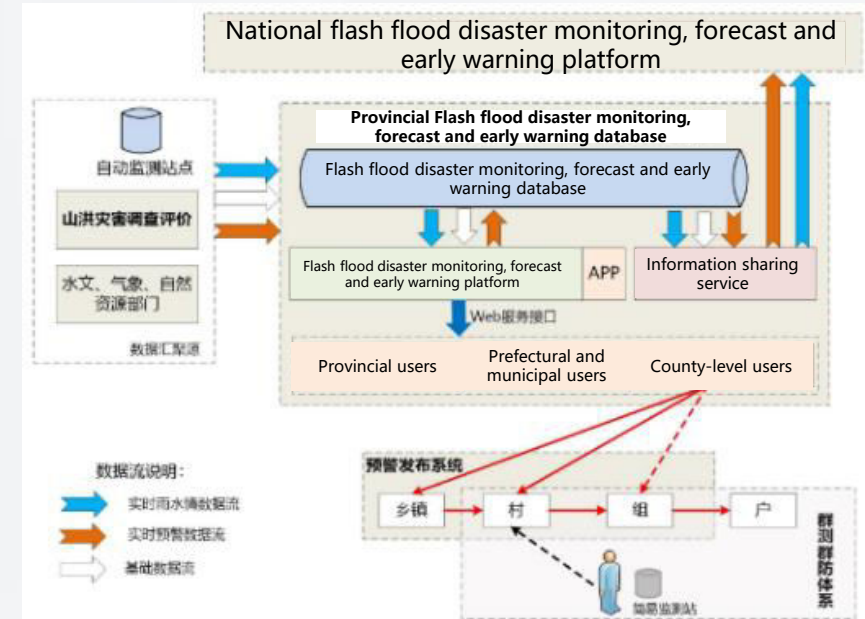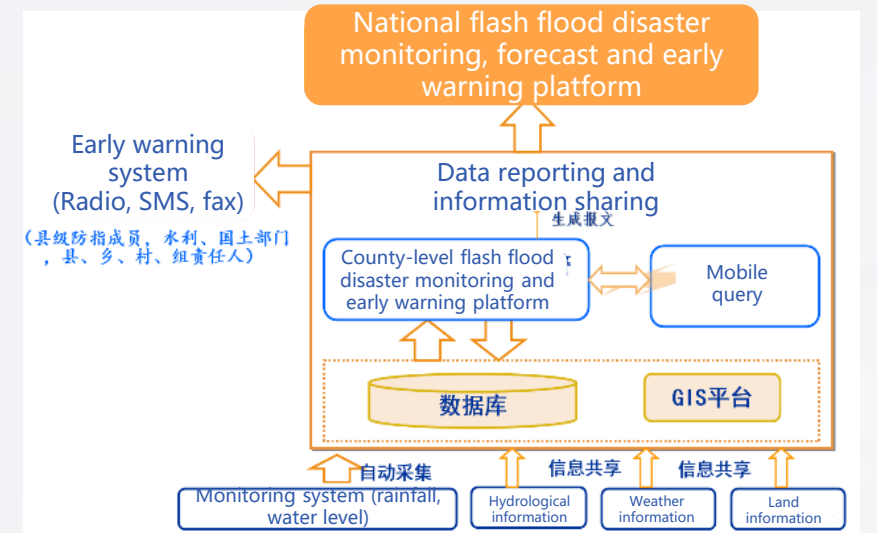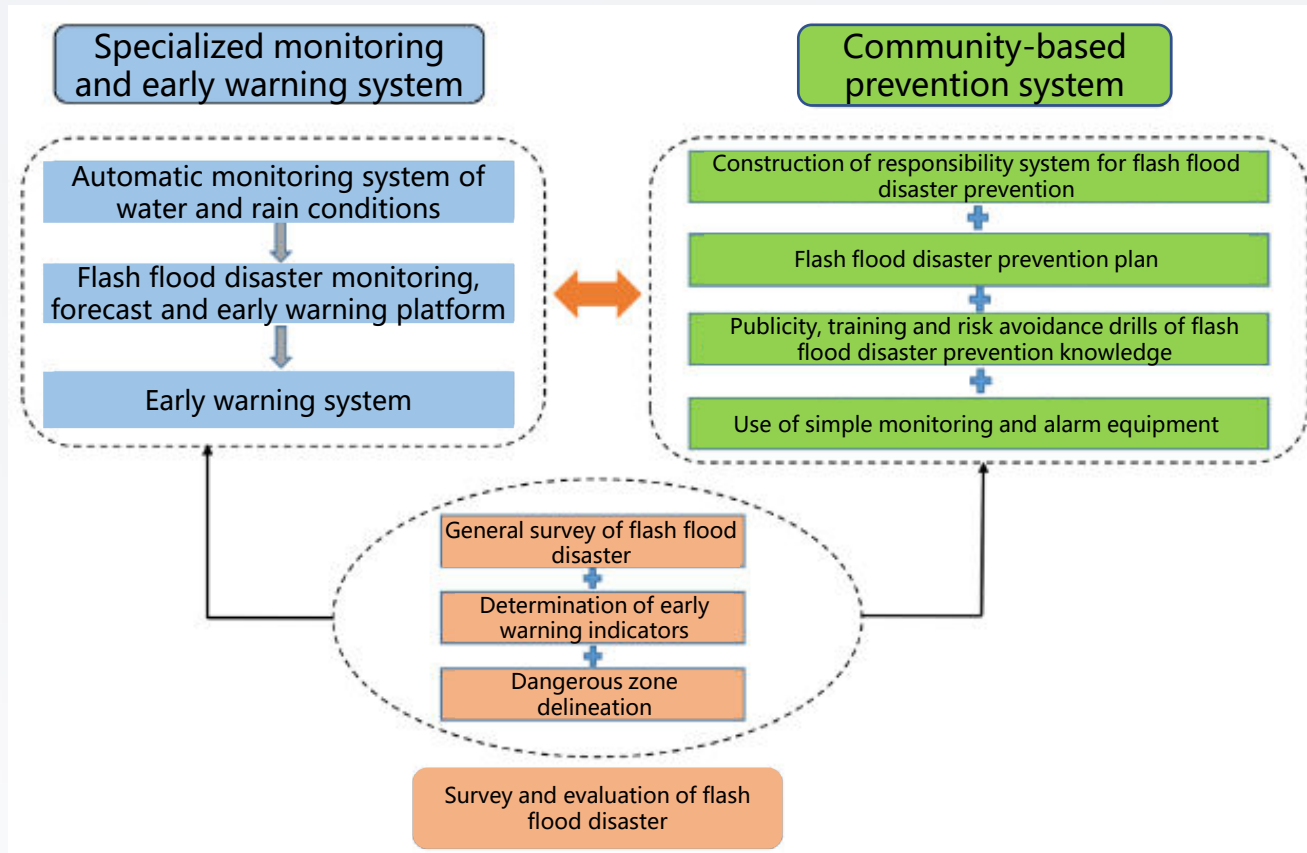- **Small watershed units: 530,000**

- **River channels: 3.68 million**

Total :102TB

National flash flood project

Spatial objects from investigation and assessment

Basemap for investigation and assessment

Comprehensive special subject map by data mining

Basic spatial data

1.57 million villages

Risk areas: 3.86 millionkm²

Past flash flood: 53.4 thousands

Project in channel: 249.8 thousands

Channel section : 170 thousand stes

Monitoring and warning instruments: 570 thousand

Past hydrometeorological data: 1475 hydrological stations, 33 thousand flood

Past flood investigation: 13 thousands

Investigated and assessed villages: 160 thousands

Administrative division

transport way

streams

2.5m DOM

state

prov.

county

Object distribution

Their Spatial distribution relationship

Spatial distribution of assessment results

Spatial data on subject

Watershed and streams

Land use and vegetation type

Soil type and texture

hydrogeological map

Watershed partition

Watershed and stream

16 spatial layer

75 attributes

Underlying surface, runoff characteristics

530 thousand unified unit hydrograph

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Overall layout of flash flood monitoring and early warning system

Specialized monitoring and early warning system

Automatic monitoring system of water and rain conditions

↓

Flash flood disaster monitoring, forecast and early warning platform

↓

Early warning system

Community-based prevention system

Construction of responsibility system for flash flood disaster prevention

✚

Flash flood disaster prevention plan

✚

Publicity, training and risk avoidance drills of flash flood disaster prevention knowledge

✚

Use of simple monitoring and alarm equipment

General survey of flash flood disaster

✚

Determination of early warning indicators

✚

Dangerous zone delineation

Survey and evaluation of flash flood disaster

National flash flood disaster monitoring, forecast and early warning platform

Early warning system (Radio, SMS, fax)
（县级防指成员，水利、国土部门，县、乡、村、组责任人）

Data reporting and information sharing
生成报文

County-level flash flood disaster monitoring and early warning platform

Mobile query

数据库 | GIS平台

自动采集 | 信息共享 | 信息共享

Monitoring system (rainfall, water level) | Hydrological information | Weather information | Land information

---

National flash flood disaster monitoring, forecast and early warning platform

自动监测站点
山洪灾害调查评价
水文、气象、自然资源部门
数据汇聚源

Provincial Flash flood disaster monitoring, forecast and early warning database

Flash flood disaster monitoring, forecast and early warning database

Flash flood disaster monitoring, forecast and early warning platform | APP | Information sharing service

Web服务接口

Provincial users | Prefectural and municipal users | County-level users

数据流说明：
实时雨水情数据流
实时预警数据流
基础数据流

预警发布系统
乡镇 → 村 → 组 → 户
群测群防体系
简易监测站

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2.1 Monitoring system

Automatic water stage station

经度:114.845769
纬度:27.972101
地址:新余市304县道
时间:2020-09-26 11:37:40
IMEI:9b64a178d6a3e111
今日水印
—相机—

Automatic rain-gauge station

卫星

人工雨量监测站

语音报讯

省级中心

INTERNET网络
或专网

无线显示告警器

GPRS/GSM短信（主备信道）

一体化雨量自动监测站

GSM/CDMA网络

GPRS/CDMA信道

中心信息
接收机

县/市级中心站

短信信道

中心短信前置接收机

水位自动监测站

Framework of flash flood automatic monitoring system

Automatic rain-gauge station： **56,067**

Automatic water stage station： **22,562**

Shared stations: **119,289**

Image and video station：

30,902

➢ **Density of rain-gauge station ≈ 34km^2**
➢ **Quantity ≈ 22 times of 2006**
➢ **Time interval for data upload 5~10 min**

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2.1 Monitoring system

Distribution map of automatic monitoring stations for flash flood disaster prevention
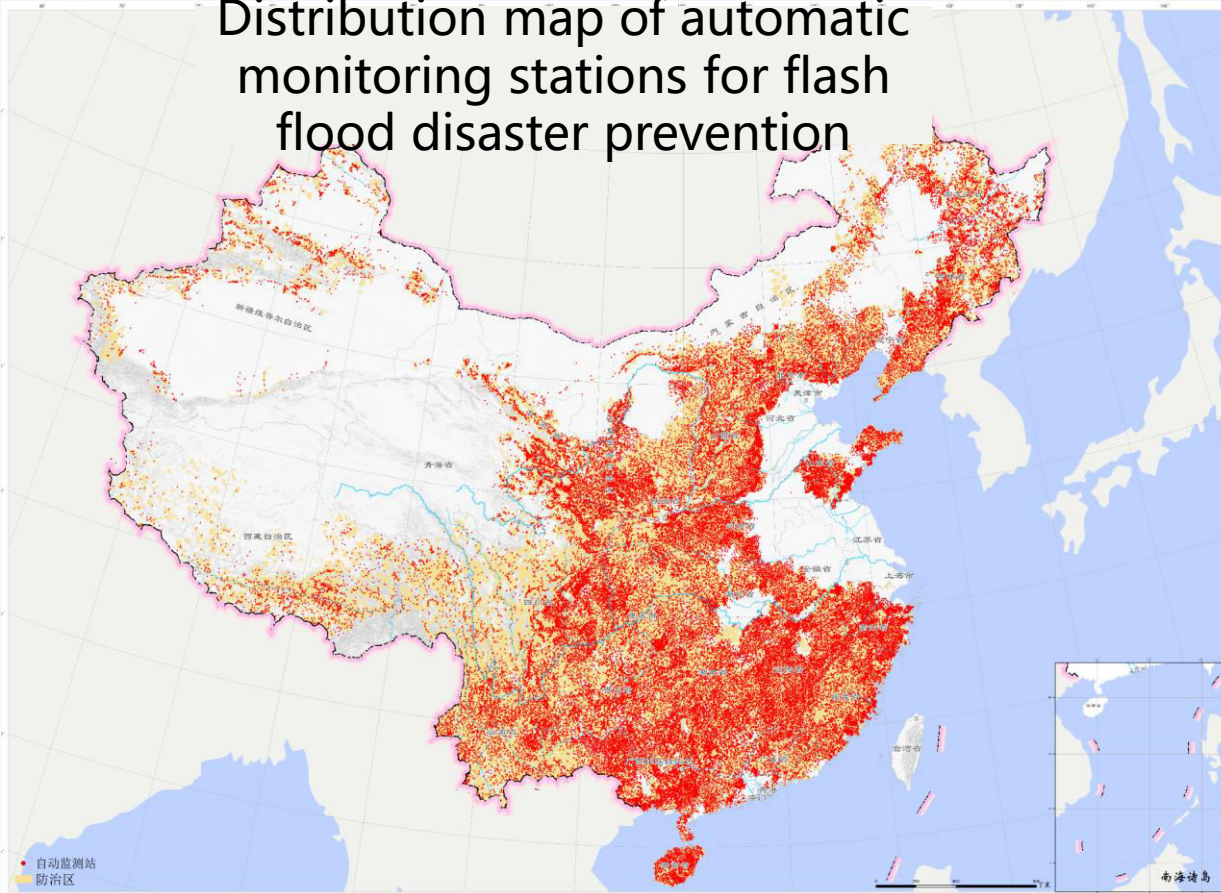
Distribution map of simple monitoring stations for flash flood disaster prevention

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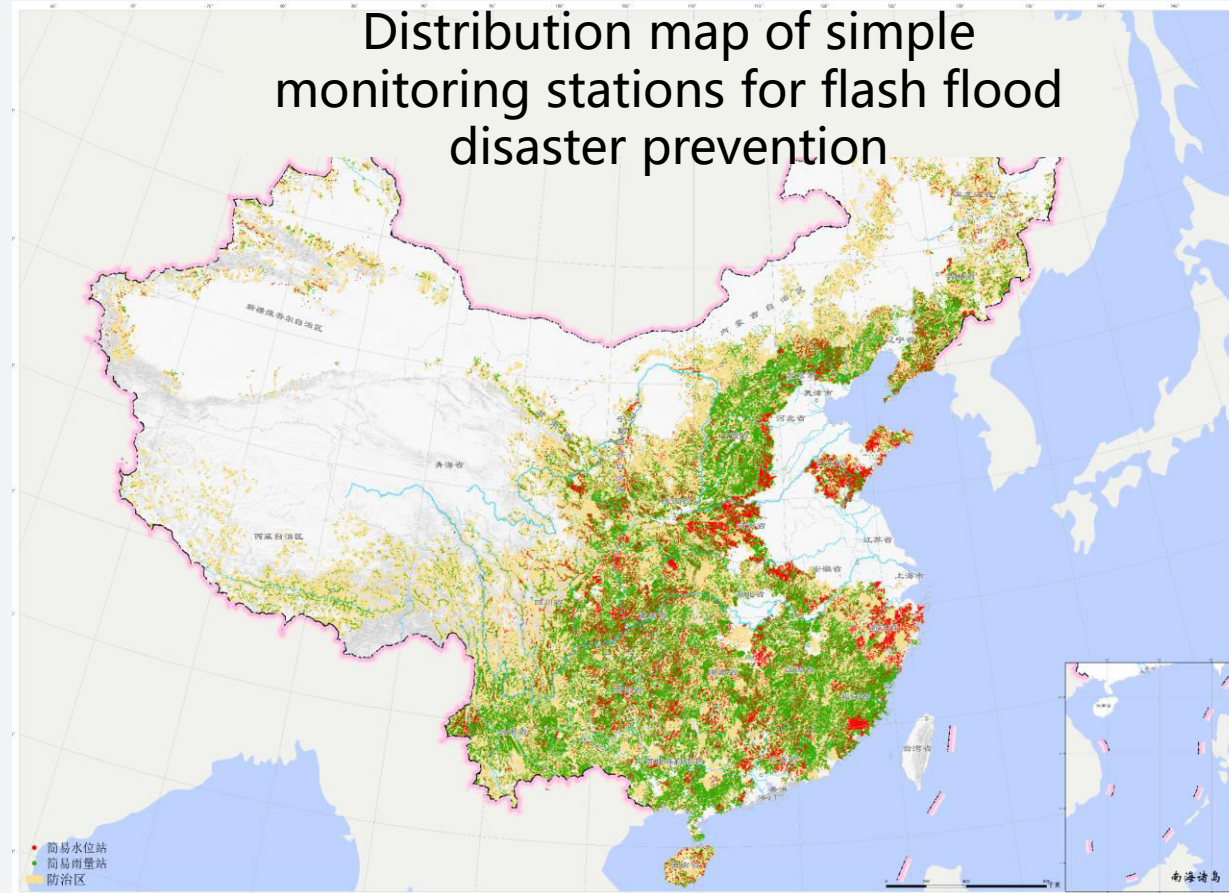
2.1 Monitoring system

- Quantity of X band radar: 22 (flash flood projects)
- Improve rainfall field monitoring capability and data transmission reliability of monitoring stations

Monitoring data

Real-time
+
Forecast

| Rainfall scatter chart | contour surface | Storm flood distribution |
| Rainfall grid | Rainfall calculation | Information query |

Beidou Satellite channel

Areal rainfall
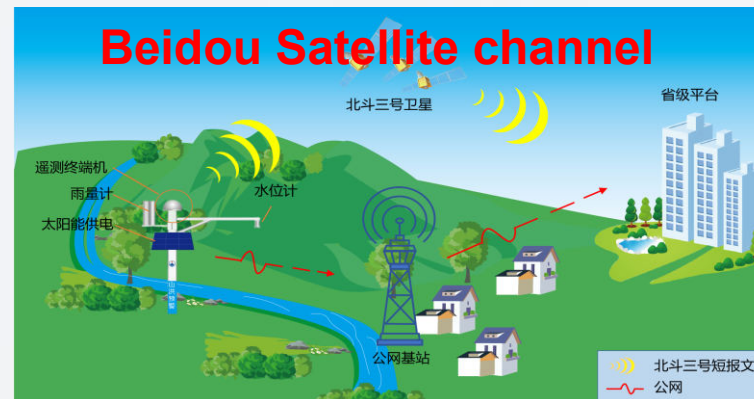
X band dual polarization rain radar
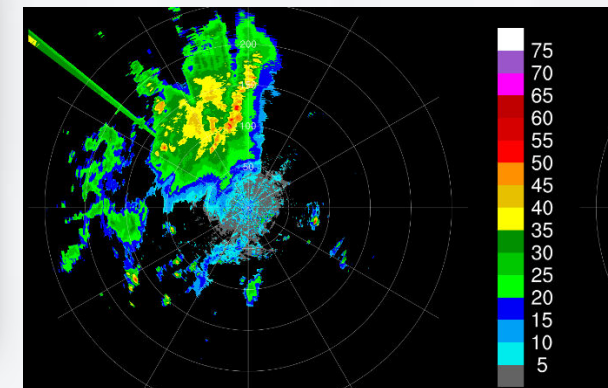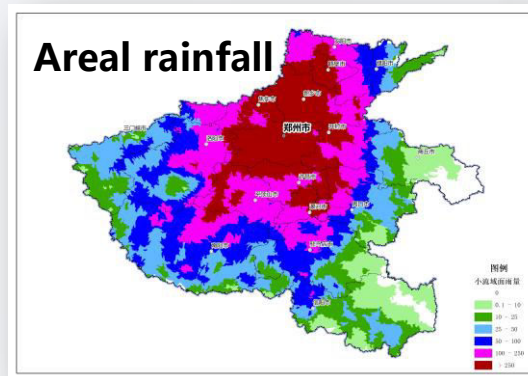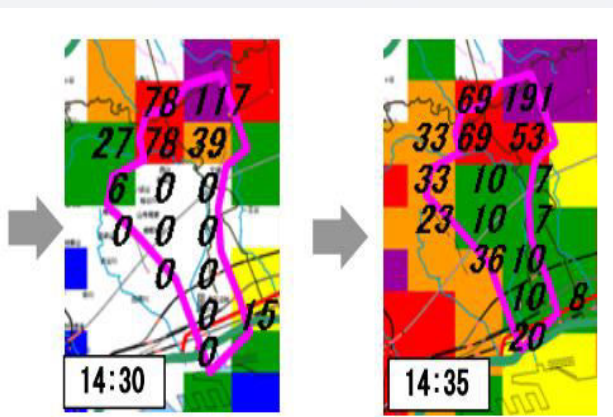
2.2 Flash flood forecast & early warning model

● **Based on underlying surface conditions and parameter regionalization by considering topography and secondary hydrological zoning and referring to provincial boundaries and physical geographical zoning, the whole country is divided into 133 forecasting and early warning zoning and 5,245 model units.**

Distributed unit hydrograph of small catchment
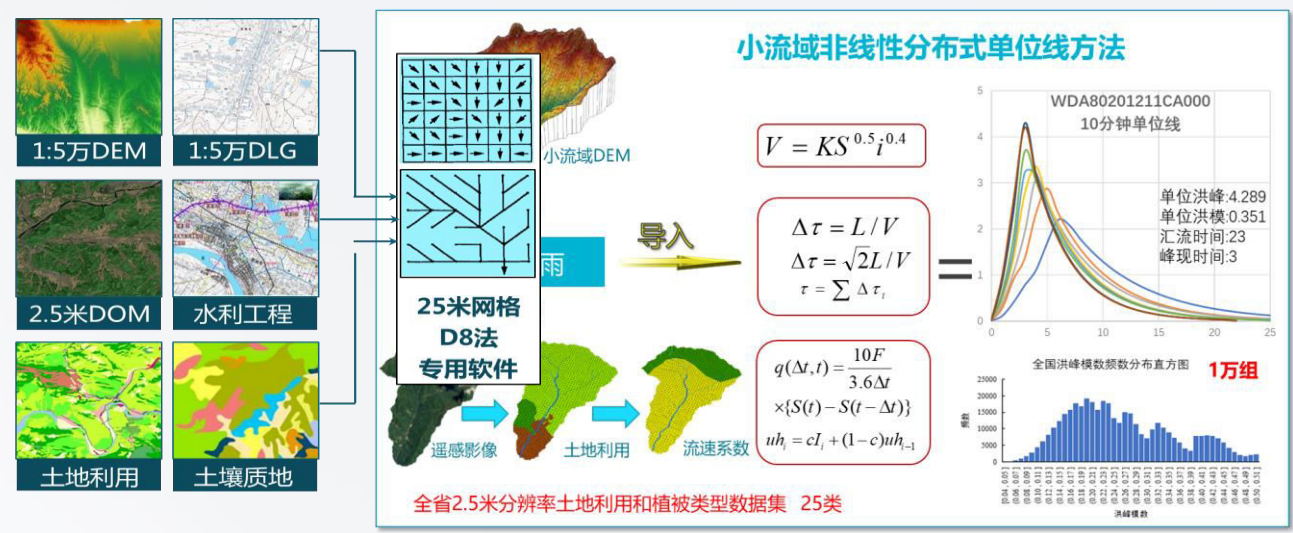
530,000 small catchments
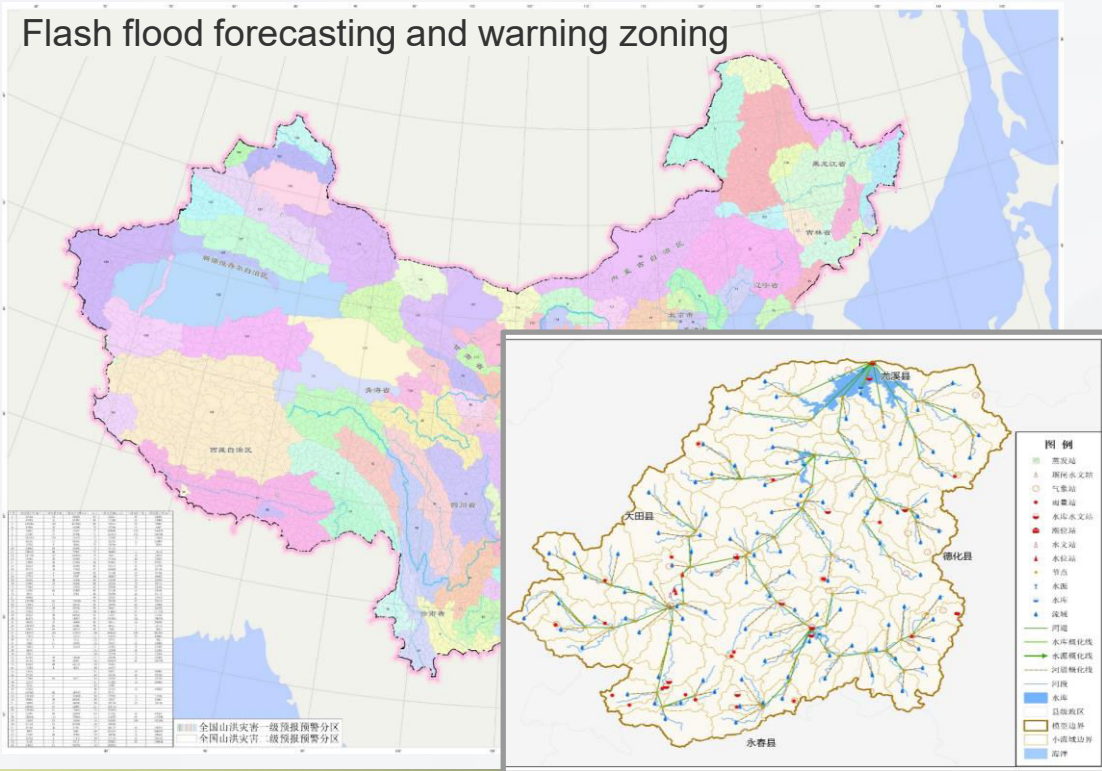
Flash flood forecasting and warning zoning

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2.2 Flash flood forecast & early warning model

● **Put forward a spatio-temporal runoff yield model and China National Flash Flood Simulation Model (CNFF) in an innovative way, and independently developed a modular distributed flash flood simulation software FFMS and a 3D visual hydrodynamic calculation software FHMS.**

Corresponding zoning of geomorphology and hydrology

Modularization

CNFF

Model base   Parameter library   Knowledge base

Time + space container

Data + target driven

Temporal and spatial combination of runoff yield and confluence models (series + parallel connection)

Model

Conversion condition   Conversion condition

Parameters of runoff yield and confluence mode

Basic parameters of small watershed

Key factor parameter library

5,245 distributed hydrological models in China

CPU/GPU heterogeneous cluster

Particle swarm optimization

SSD file system

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2.2 Flash flood forecast & early warning model

● **The dynamic simulation model of soil water content and potential evapotranspiration model have been developed, and daily potential evapotranspiration map at 1km grid and soil moisture map products for flash flood forecasting and early warning have been released for the first time (http://www.qgshzh.com/).**

全国日蒸发量（mm）
2021年6月10日20时至11日20时
中国水科院减灾中心

图 例
>= 8
6 - 8
4 - 6
2 - 4
0 - 2
0
1：11 000 000
审图号：GS(2020)4634号
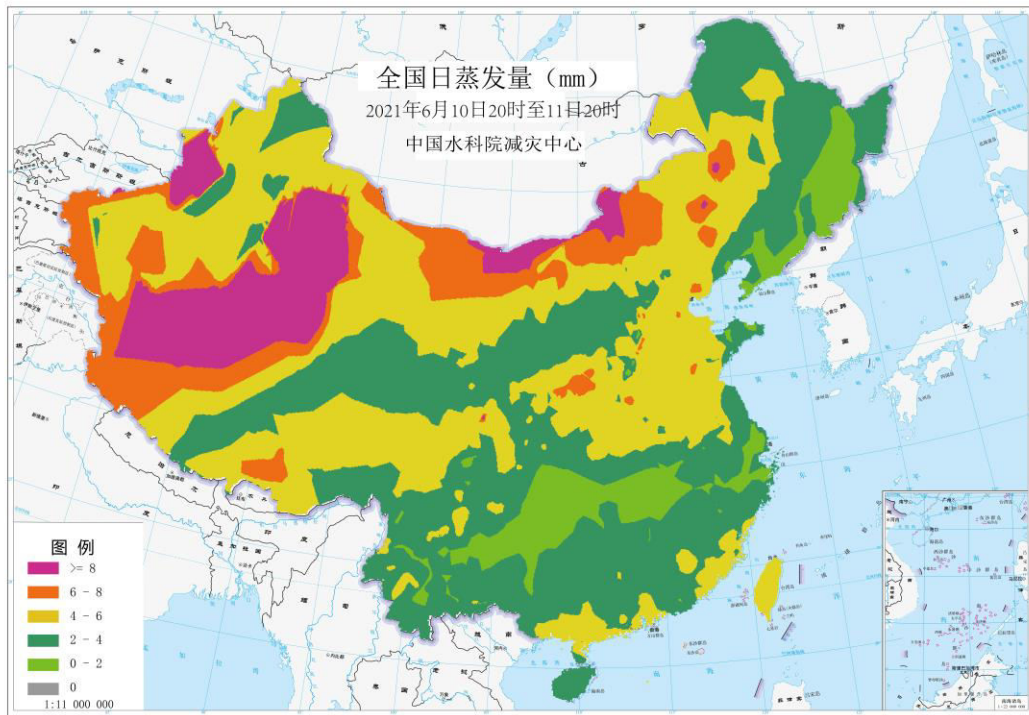
National Daily PET Map

PET model

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \dfrac{900}{T_{mean} + 273} u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

Soil moisture dynamic model

$$\begin{cases} \dfrac{\partial \theta(z,t)}{\partial t} = -\dfrac{\partial q_v}{\partial z} + s(z,t) \\[2mm] q_v = -K(\theta, z)\left[\dfrac{\partial \Psi(\theta)}{\partial z} - 1\right] \end{cases}$$

$$\begin{cases} -K(h)\dfrac{\partial h}{\partial z} + 1 = R, \quad \theta(0,t) \le \theta_s, \quad t \le t_p \\[2mm] h = h_0, \quad \theta(0,t) = \theta_s, \quad t > t_p \end{cases}$$

30厘米土壤相对湿度（%）
2021年06月11日
中国水科院减灾中心

图 例
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1：11 000 000
审图号：GS(2020)4634号
8时土壤水分模拟
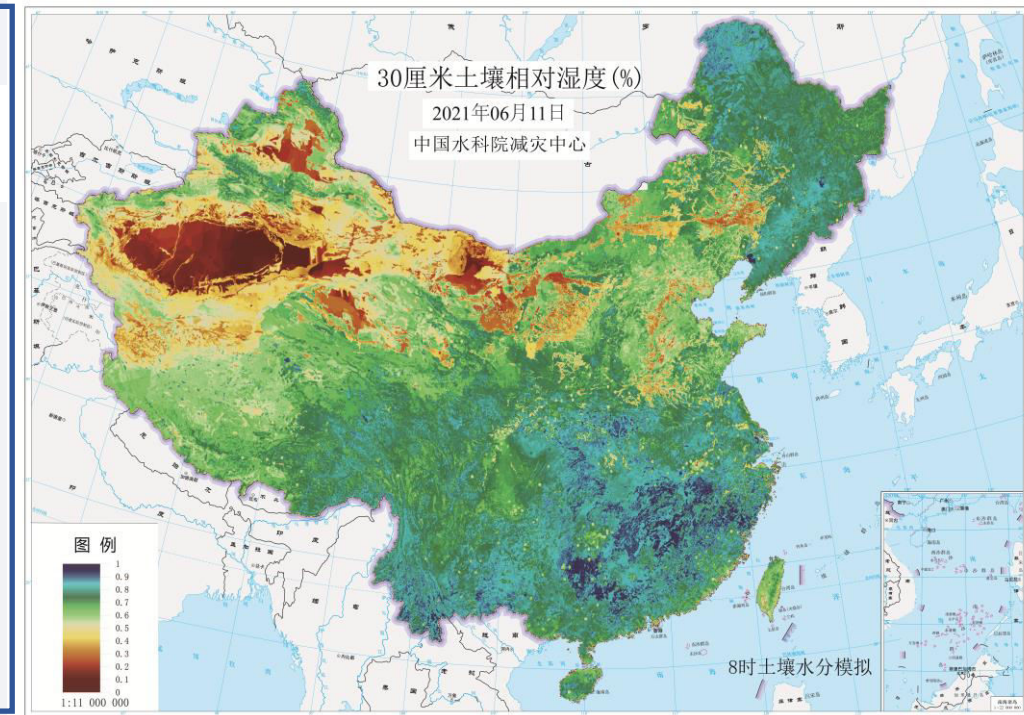
National Daily Soil Moisture Map

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2.2 Flash flood forecast & early warning model

● **Put forward a dynamic critical rainfall analysis method reflecting the change of soil water content and the nonlinear characteristics of runoff yield and confluence in small watersheds without data, the early warning accuracy improved by more than 20%.**


Water stage - discharge - population - elevation relationship

Hazard map

Method of dynamic early warning index
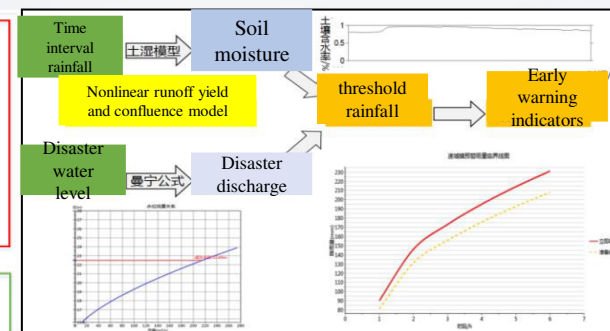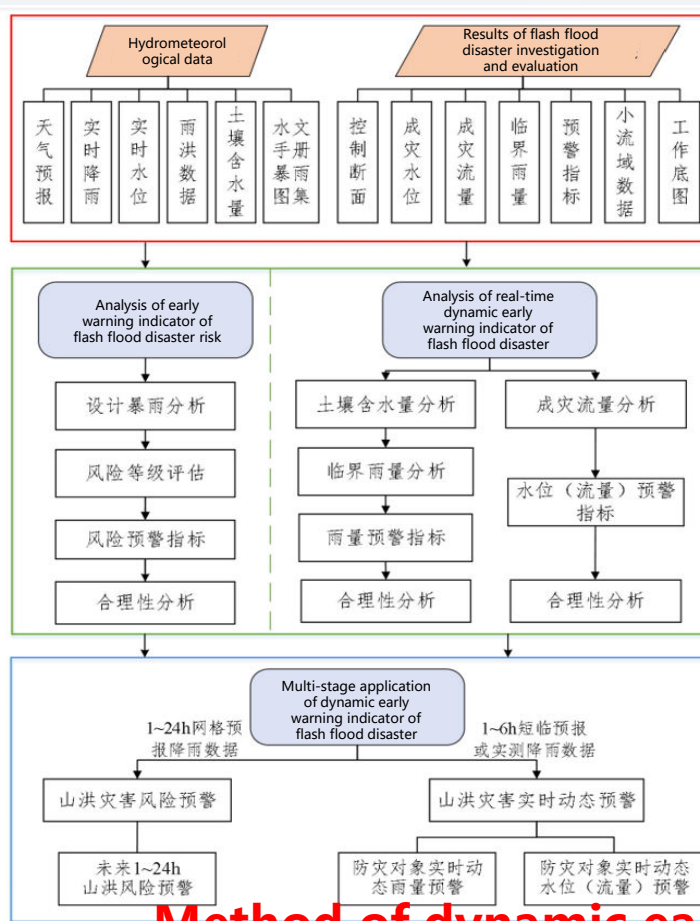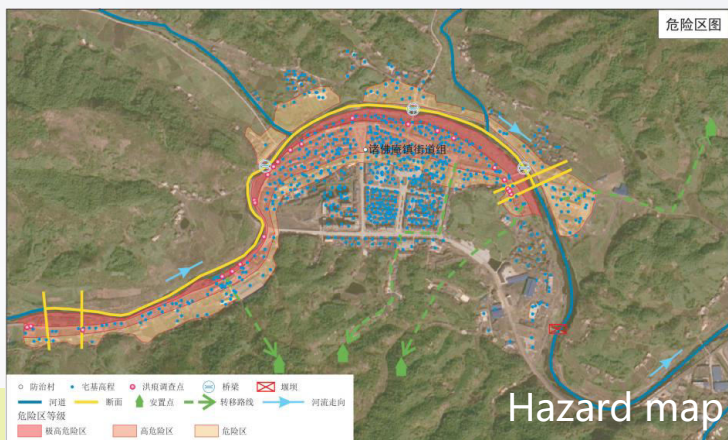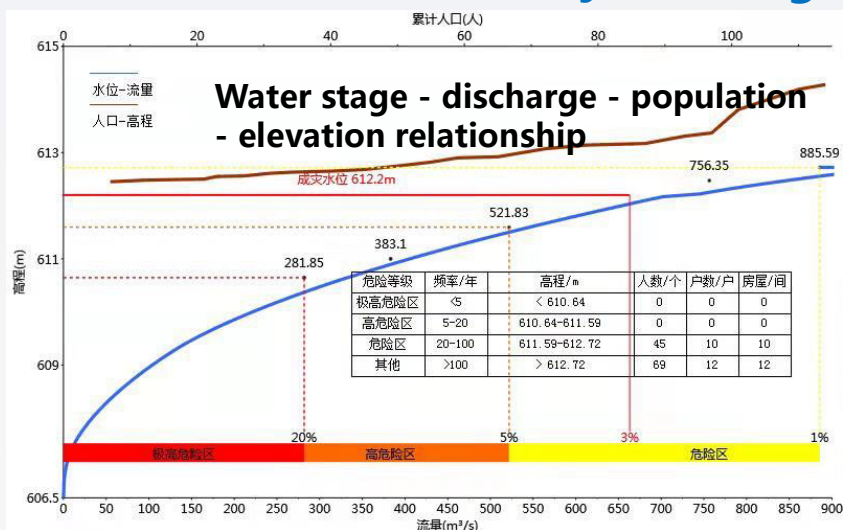
土壤含水量 (%W_m)	时段	临界雨量/mm	
		准备转移指标/mm	立即转移指标/mm
20	1 小时	69	76
	2 小时	74	82
	3 小时	87	97
	4 小时	96	107
	5 小时	105	116
	6 小时 (τ)	111	124
50	1 小时	80	88
	2 小时	82	90
	3 小时	89	99
	4 小时	98	108
	5 小时	107	118
	6 小时 (τ)	112	125
80	1 小时	102	109
	2 小时	103	111
	3 小时	106	114
	4 小时	116	125
	5 小时	126	136
	6 小时 (τ)	126	136

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2.3 Flash flood forecast & early warning platform

- ➤ **1 national platform**
- ➤ **30 provincial platforms**
- ➤ **2076 county platforms**

Monitoring and warning information management system at national, provincial and municipal level
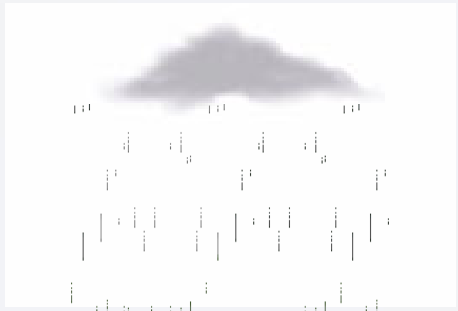
Alert system

Automatic Monitoring

(56067 Rain-gauge and 22562 stage gauge)
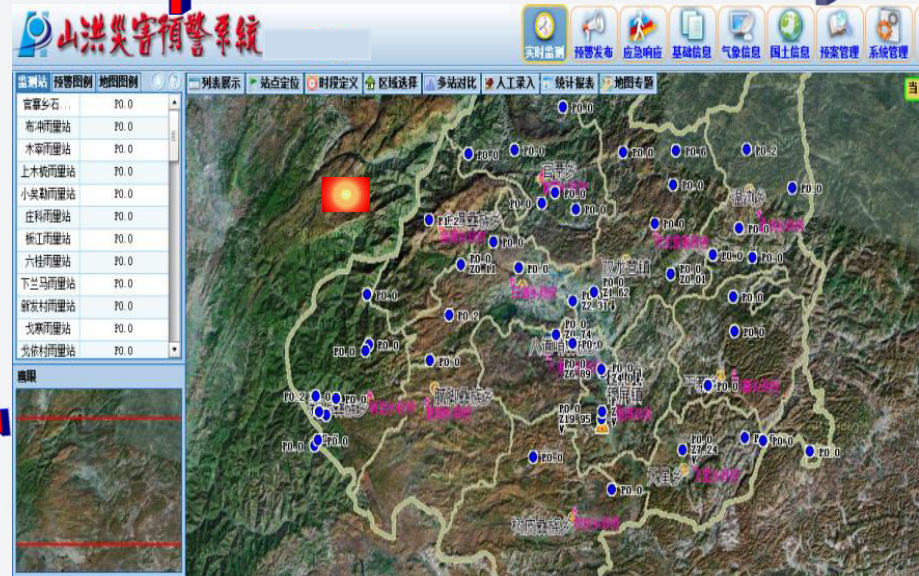
County-level monitoring and warning platform

Warning message transfer, evacuation

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2.3 Flash flood forecast & early warning platform

County-level monitoring and early warning platform

Integrated services → Monitoring and early warning → Early warning release → Emergency response → Cancellation of early warning → Disaster statistics

The system automatically extracts the real-time rainfall and determines the early warning status according to thresholds pre-set. Then, the early warning level and dangerous areas are determined as per the correlation characteristics between small watersheds and administrative regions, and the early warning information is released. It has become a business platform for daily flood prevention and decision support of county-level water conservancy departments.

Miao pit	24.33
Leshanzi	28.21
Qile pit	22.45

Automatic rainfall monitoring station

GSM/GPRS

Hydrological monitoring station

GSM/GPRS

Meteorological station

GSM/GPRS

Water and rainfall monitoring platform

internet

Monitoring and early warning system

Analysis and query

Analysis and calculation

Administrative area

Small watershed

Threshold setting
Threshold comparison

Transfer preparation

Immediate transfer

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2.3 Flash flood forecast & early warning platform

Provincial monitoring and early warning platform

- At present, the provincial platform has the comprehensive data and the high operation and maintenance effect. The functions mainly include early warning monitoring, water and rainfall situations, meteorology, early warning response, basic information, disaster bulletin, platform use monitoring, data maintenance and so on.
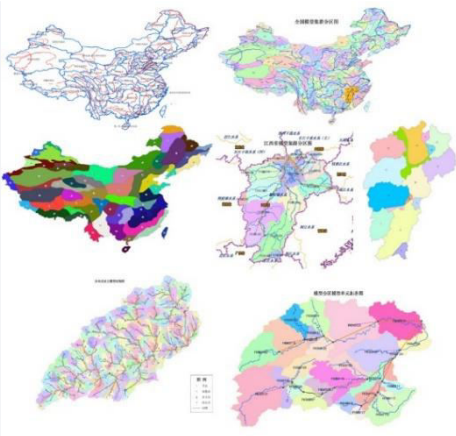
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2.3 Flash flood forecast & early warning platform

National monitoring and early warning platform

- The functions mainly include rainfall monitoring, early warning, flash flood analysis, etc., and a large number of reliable basic data are stored.

133 clusters 5245 model units

CNFF model suite

Characteristics and advantages of national platform

Big data	**200TB**
High storage	**600TB**
Full-coverage	**Mountainous areas**
High performance	**<2min**
Hyperfine	**530,000 small watersheds**
High precision	**Hit rate > 60%**
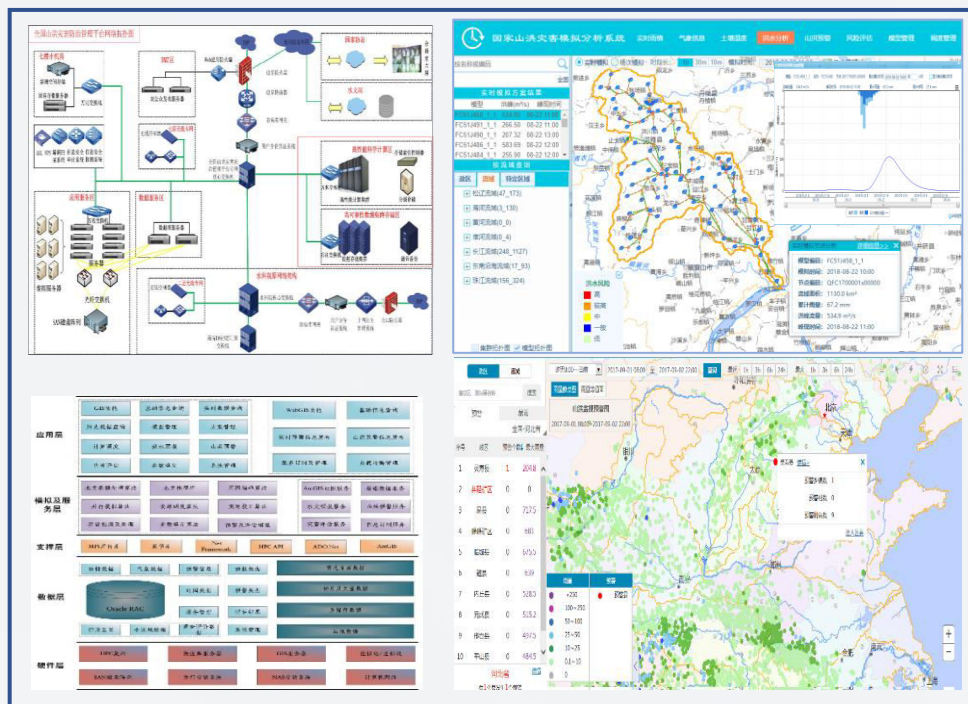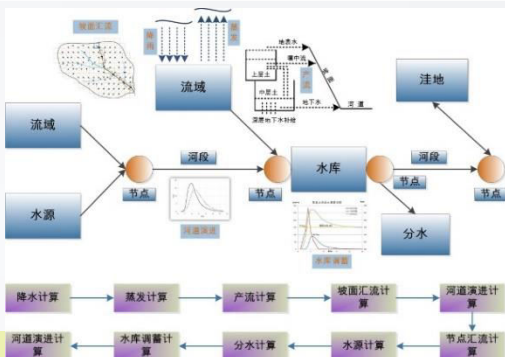
High-performance scientific computing cluster
High-speed information exchange network
Meteorological and satellite multi-source information reception

National flash flood disaster survey and evaluation results management system
National flash flood disaster simulation and analysis system
National flash flood disaster monitoring and early warning information management system

2.3 Flash flood forecast & early warning platform
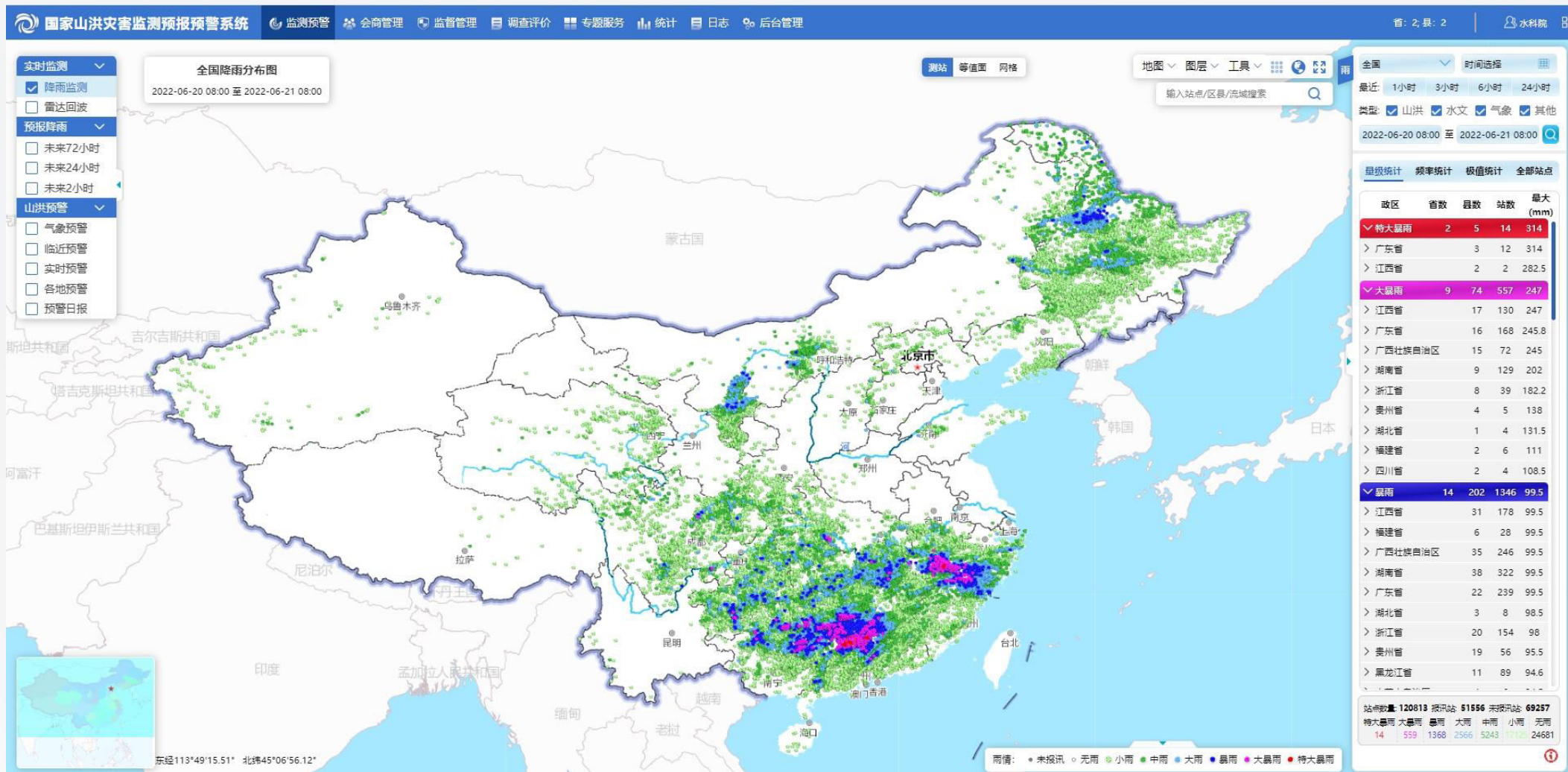
National monitoring, forecasting and early warning platform

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2.4 Community-based prevention system

County → Township → Village → Community → Household

Responsibility system

County level — Commander, Vice commander, Member → County headquarter → Office, Workgroup, Emergency rescue team → Monitoring, Information, Evacuation, Coordination, Supporting

Town level — Commander, Vice commander, Member → Town headquarter → Workgroup, Emergency rescue team → Monitoring, Information, Evacuation, Coordination, Supporting

Village level — Village headquarter → Morning & Warning, Emergency rescue team, Evacuation group → Resident A, Resident B, Resident C, …

每个行政村
"十个一"

preparedness plan

responsibility system

rain gauge station

alert device

training per year

drill per year

publicity board

drill per year

alert plate

must-know card

Warning facility
1,190,000

Training & drill
1,291,000

Publicity board
810,000

Must-know card
79,550,000

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2.4 Community-based prevention system

- **Expand multi-approach for warning message delivery to residents and mobile population**

Beidou satellite hand terminal

APP

Rain-gauge and water stage alarm station

Indoor broadcasting and warning station
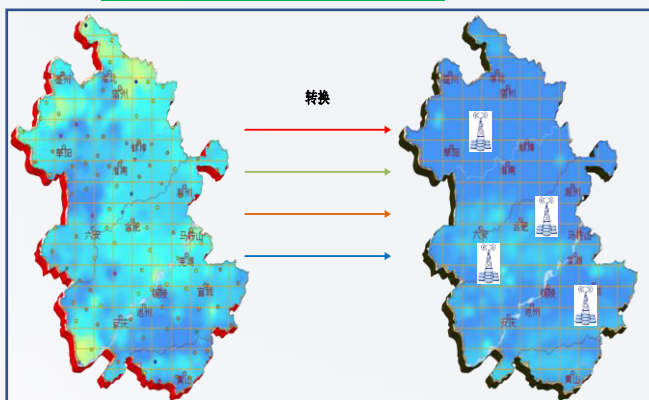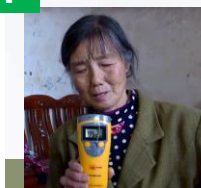
Targeted release of early warning information based on location big data

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3.1 Multi-stage progressive monitoring and early warning system of flash flood disaster has established and applied in China

Flash flood simulation
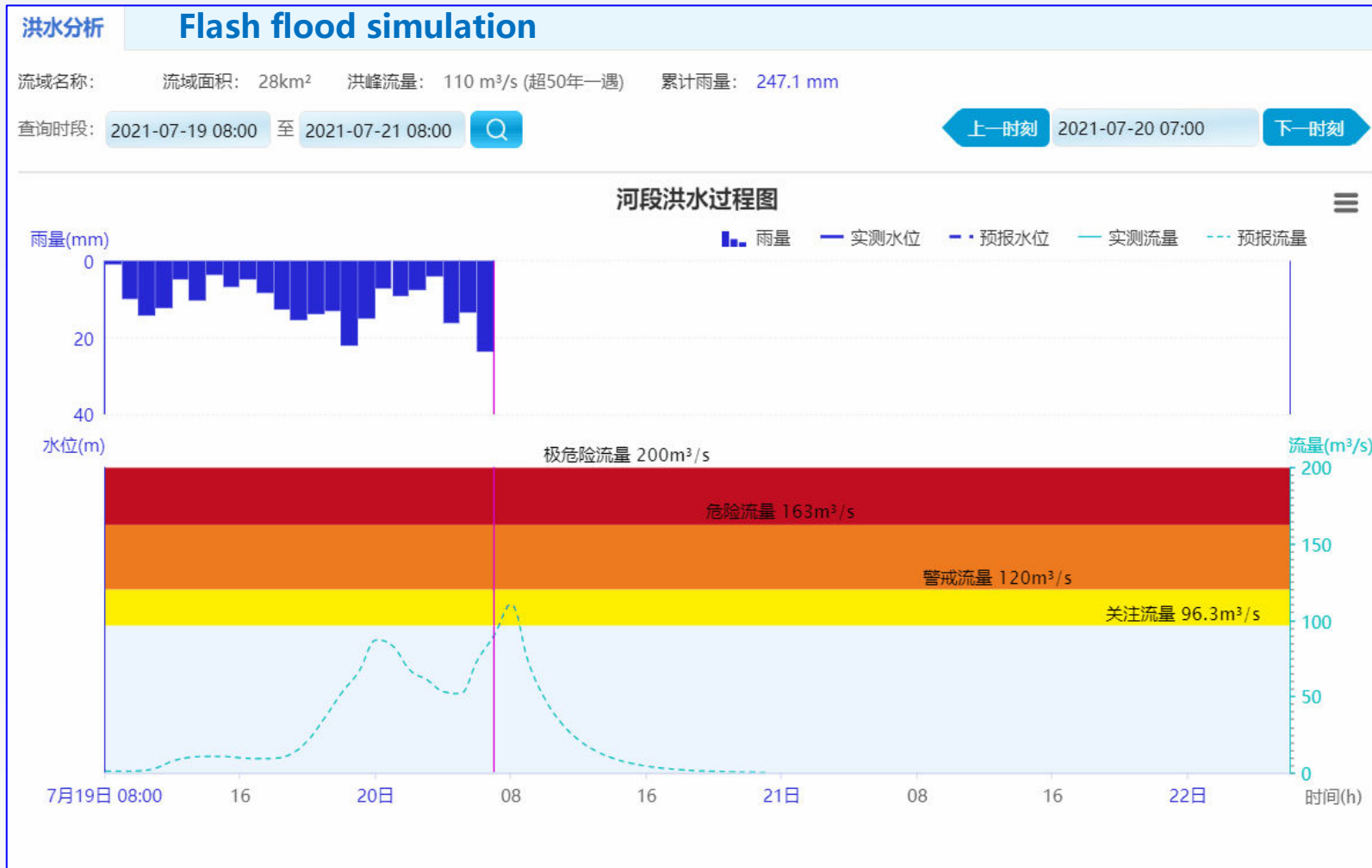
24 h forecast & warning based on meteorological data

1-6 h nowcasting forecast & warning

Real-time monitoring & warning

Risk level

| Very high | High | Medium | Low |

Warning message dissemination

3.1 Multi-stage progressive monitoring and early warning system of flash flood disaster has established and applied in China

Dynamic early warning in Fujian Province

Meteorological early warning

Real-time rolling early warning

- ✓ Realize **multi-stage dynamic early warning** of flash flood disaster (meteorological early warning, real-time early warning, nowcasting and early warning);
- ✓ Conduct rolling release of the flood early warning level and time of disaster prevention objects such as flash flood early warning areas, villages along the river, rivers and reservoirs in the hilly areas of the province, and realize the **refined early warning and forecast** of flash flood disasters.
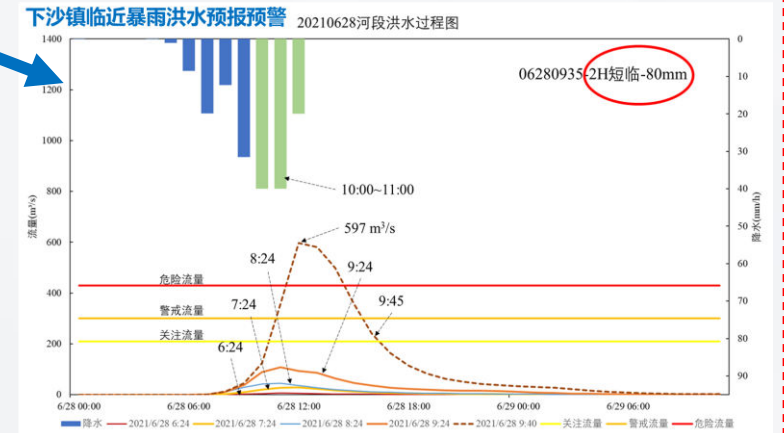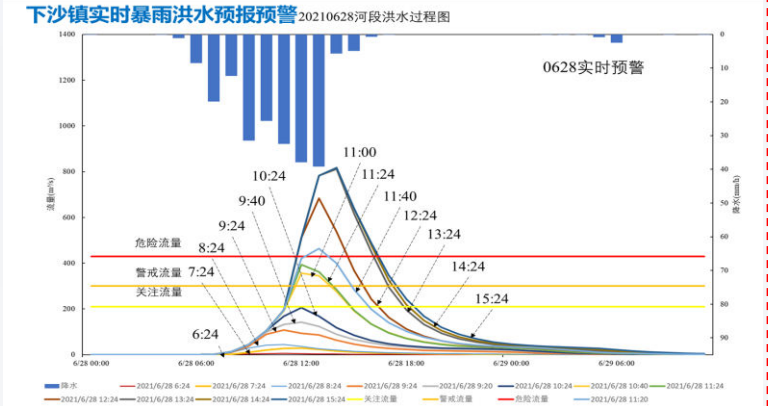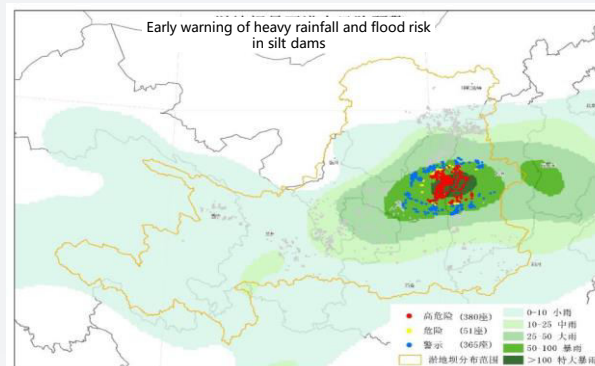
Nowcasting and early warning

3.2 Used for flash flood risk warning based on meteorological data during flood seasons
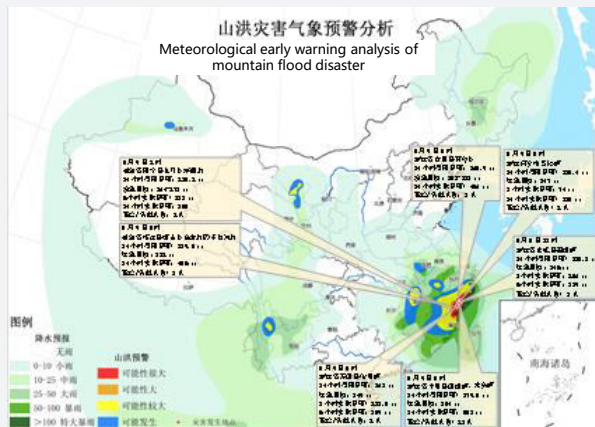
Meteorological early warning analysis of mountain flood disaster

Early warning of heavy rainfall and flood risk in silt dams

General survey of flood and drought disaster risk
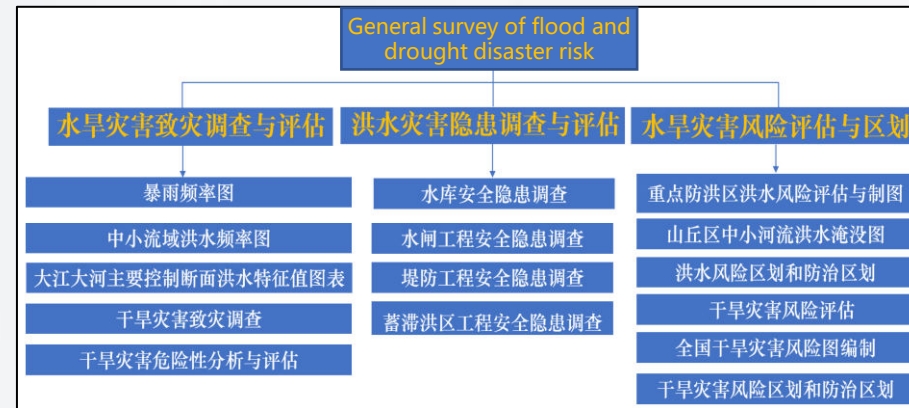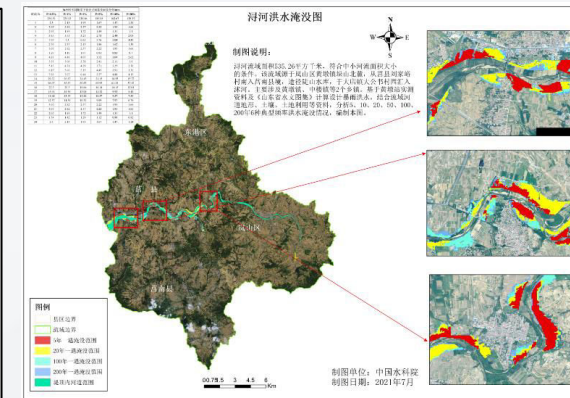
- **Up to Aug 2023, a total of 1101 episodes of meteorological early warnings for flash flood disaster have been produced and sent, of which 286 were broadcast on CCTV weather forecast program.**

- **The results also played an important role in the comprehensive risk survey of national natural disasters.**
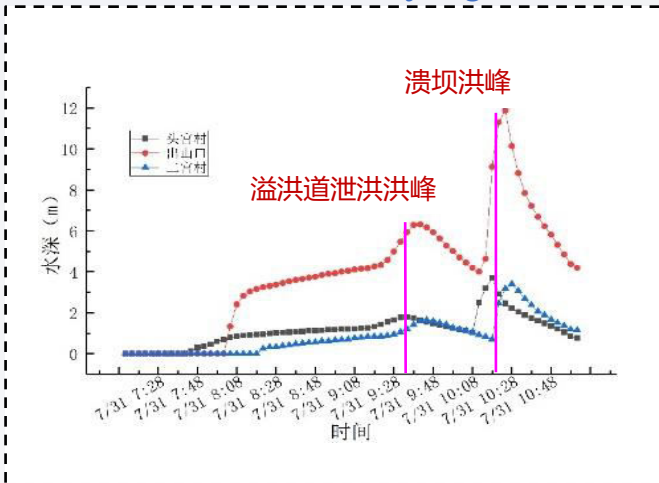
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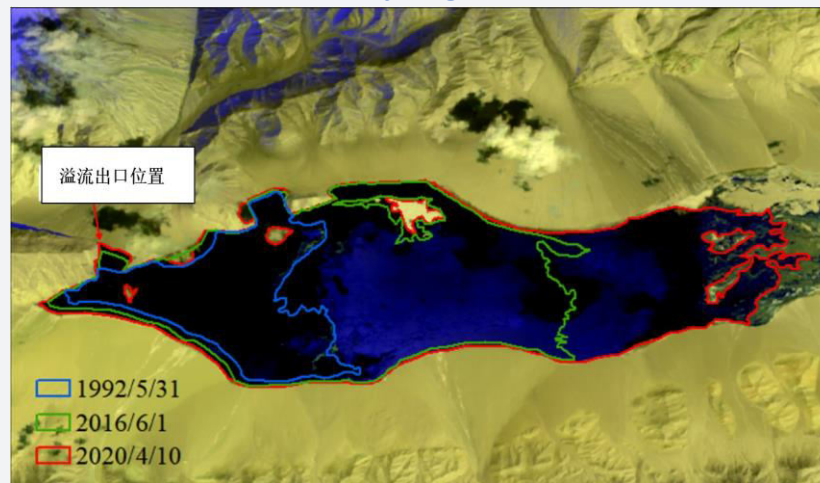
3.3 Support disaster analysis

- **Analysis of dam break of Sheyuegou Reservoir in Xinjiang**
- **Risk assessment of Kule Lake collapse in Aksu, Xinjiang**
- **Survey on "7·20" extraordinary rainstorm disaster in Zhengzhou, Henan Province**

- **Survey on "7.11" flash flood disaster in Zezhou, Shanxi Province**
- **Survey on "8.12" flash flood disaster in Liulin, Hubei Province**
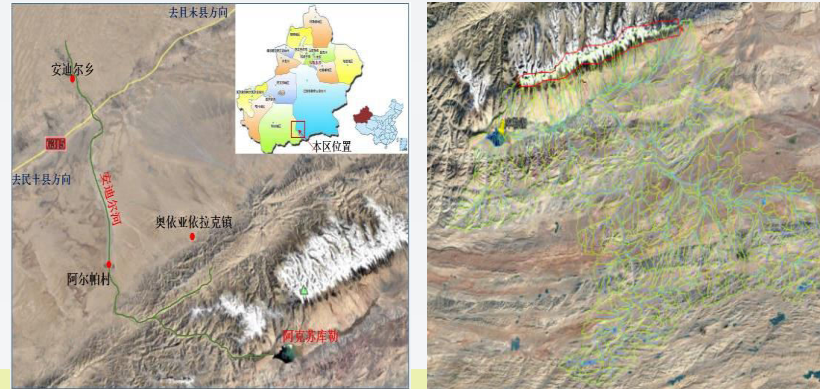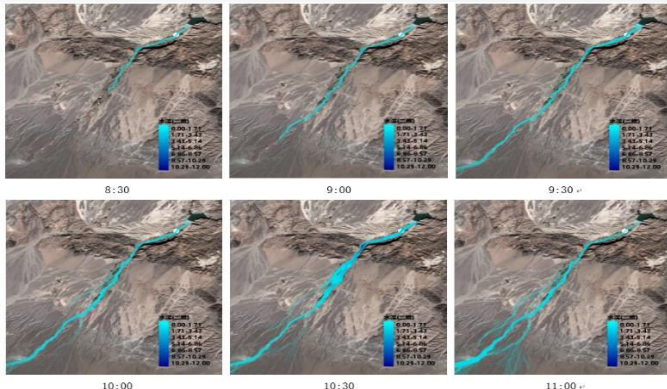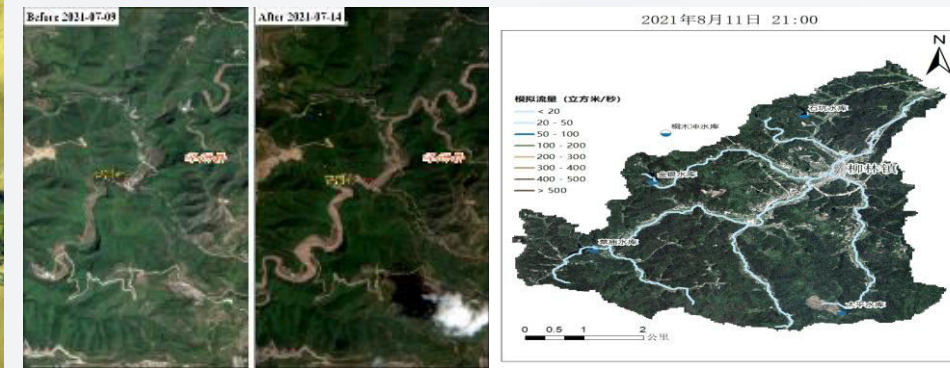- **......**

Survey on dam break of Sheyuegou Reservoir in Xinjiang

Risk assessment of Kule Lake collapse in Aksu, Xinjiang

Survey on typical flash flood disaster

溃坝洪峰

溢洪道泄洪洪峰

溢流出口位置

1992/5/31
2016/6/1
2020/4/10

Before 2021-07-09 After 2021-07-14 2021年8月11日 21:00

受灾严重的沿河村落河道设计洪水计算表

市	镇	村	所在河流	上游面积 km²	模拟洪峰 m³/s	模拟设计暴雨下的洪峰流量 m³/s						
						5 年	10 年	20 年	50 年	100 年	500 年	1000 年
荥阳市	崔庙镇	王宗店	索河	21.35	414	150	183	190	233	270	520	545
	崔庙镇	海沟寨	索河	40.95	754	160	287	131	151	198	1053	1219
	高山镇	许村	汜河	27.96	322	113	161	203	225	258	579	599
	贾峪镇	上湾村	贾峪河	13.36	403	38	51	55	69	81	291	319
	汜水镇	老君堂	汜河	6.26	117	5	9	17	32	46	272	303
新密市	城关镇	东瓦店村	双洎河	232.72	2159	784	900	1351	1986	2439	6761	7213
	西大街办事处	下庄村	双洎河	7.98	130	25	41	35	44	51	138	144
	米河镇	米河镇	汜河	209.63	4974	608	805	1001	1238	1347	3413	3849
巩义市	小关镇	小关镇	汜河	13.70	286	50	72	94	101	125	517	573
	河洛镇	洛口	洛口东沟	11.08	372	36	55	80	100	398	440	
登封市	告成镇	告成镇	石淙河	139.92	817	411	461	540	630	677	1376	1466

Investigation of stormflood in Zhengzhou, Henan Province

XVIII
World Water Congress
International Water Resources Association (IWRA)

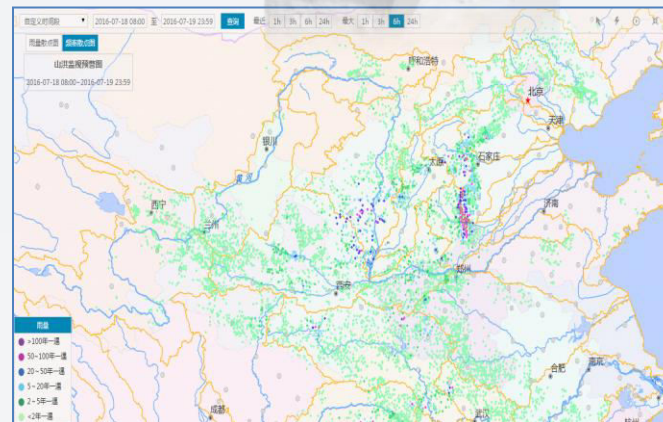● **Disaster mitigation benefits**

2012~2023
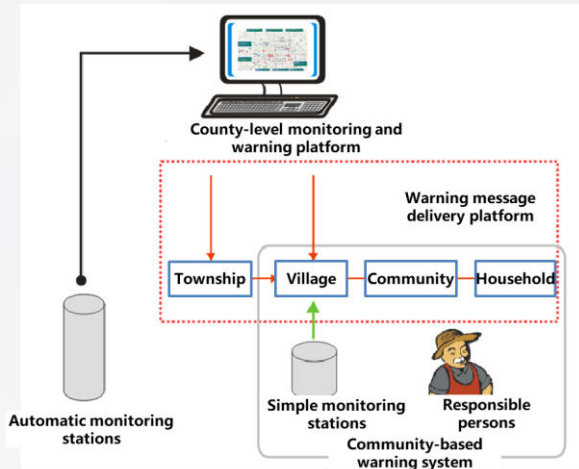
Typical flash flood disasters
961 events happened

County-level flash flood
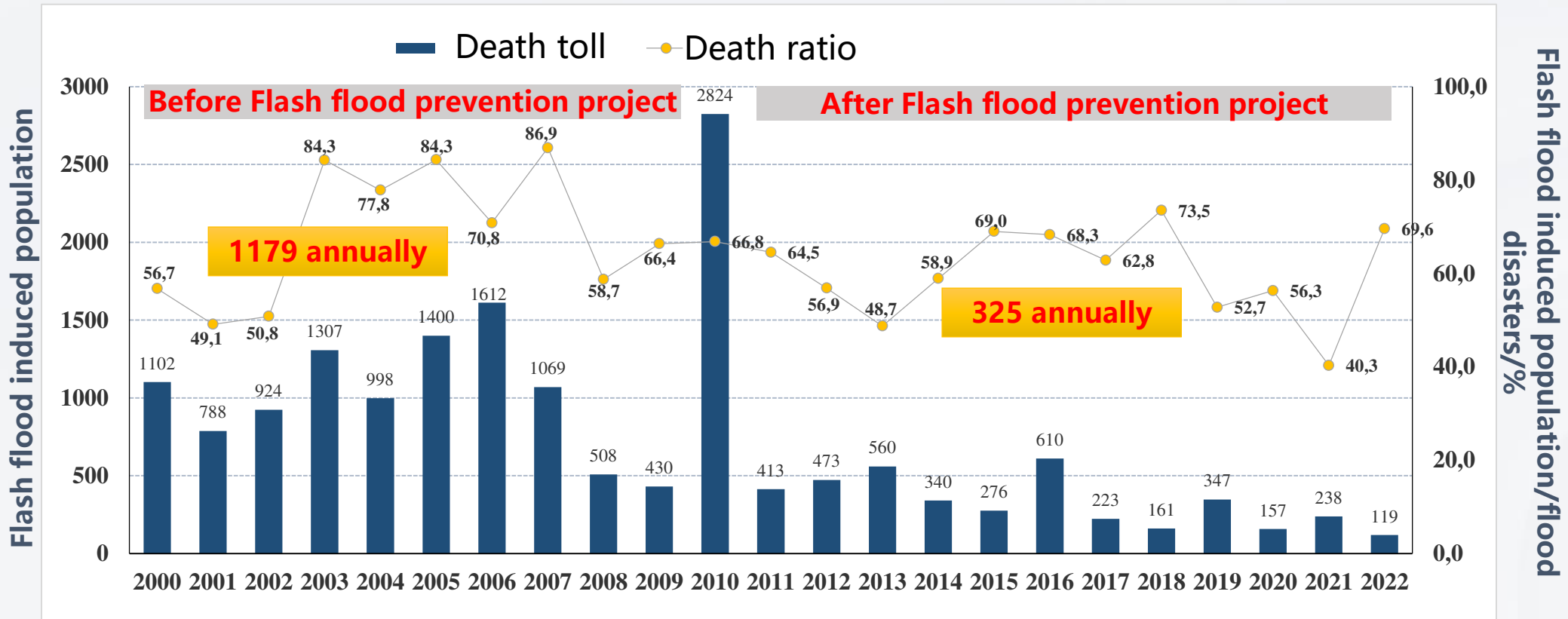disaster warning dissemination
11.7 million issued

Warning message delivery for
local responsible persons
286 million delivered

Warning message delivery for
the public
5.22 billion delivered

● **Effectiveness**

In the past 10 years, **the number of deaths caused by flash flood disaster in China has decreased by more than 70%.**

Local governments and the public praised the project as the "umbrella for life safety" and "the project of cost-saving, efficient and beneficial to people's livelihood"

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Email: sundy@iwhr.com, zhangxl@iwhr.com