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Hydrometeorological Extremes simulatioN Group

Flood risk assessment and response under climate change from global to local scales

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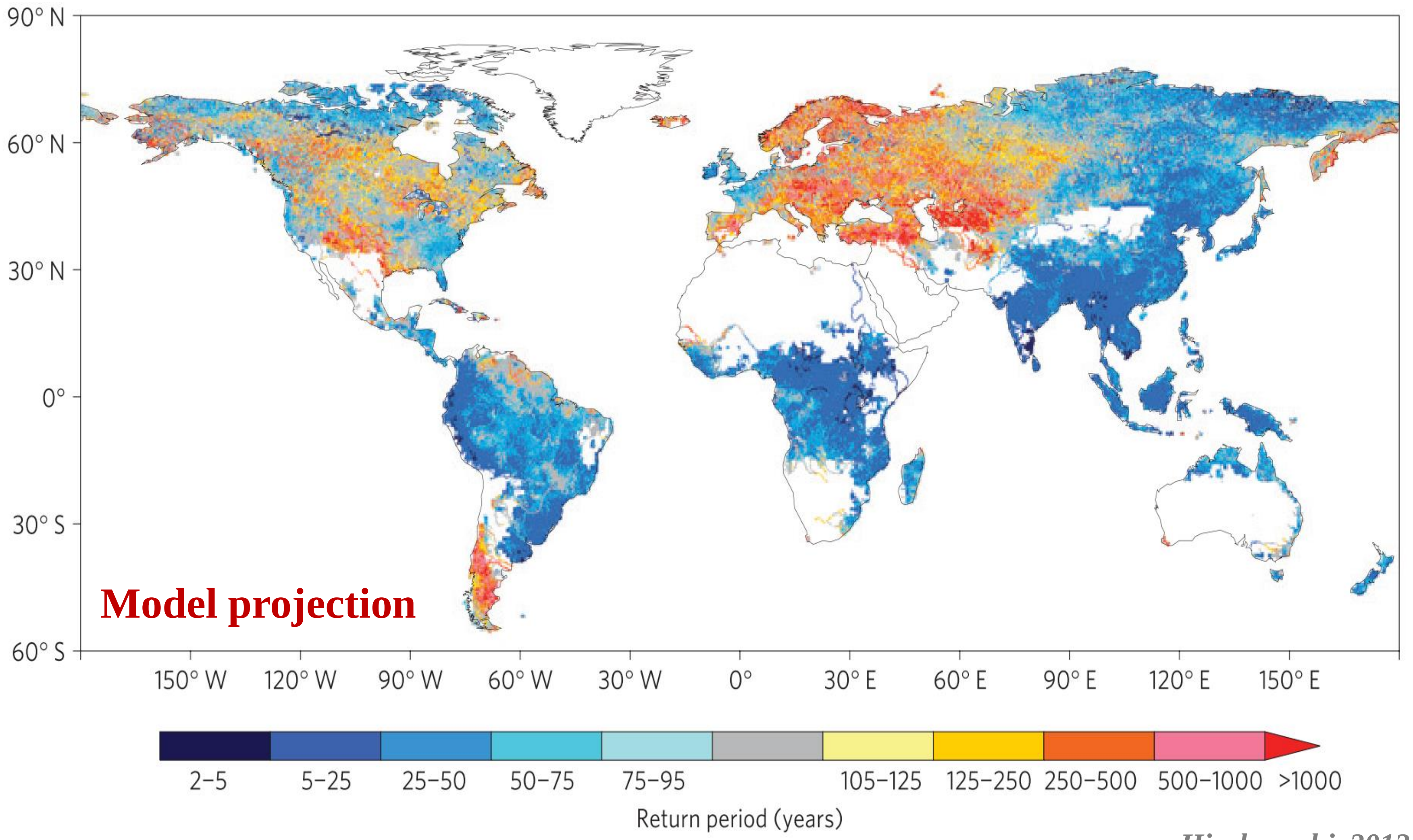
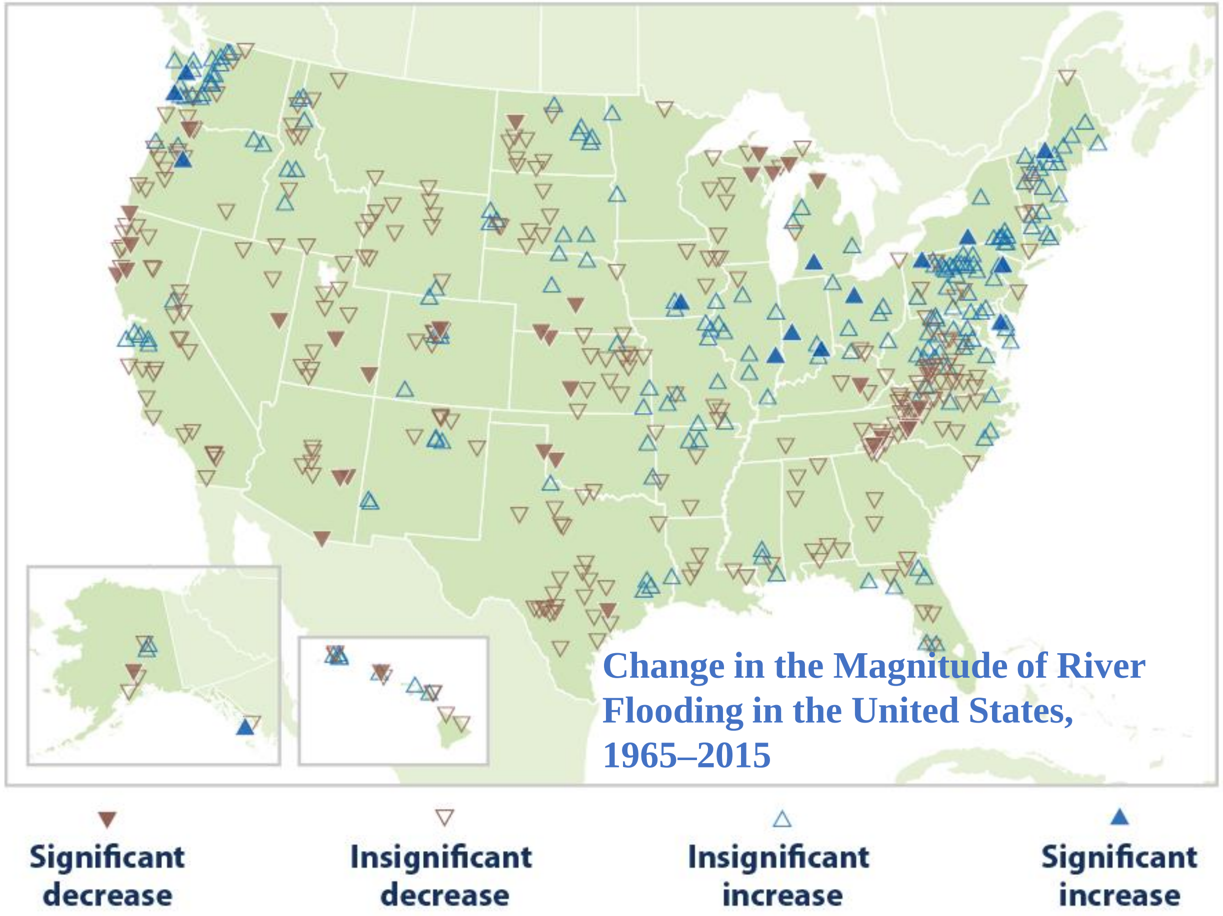
Projection of future flood change

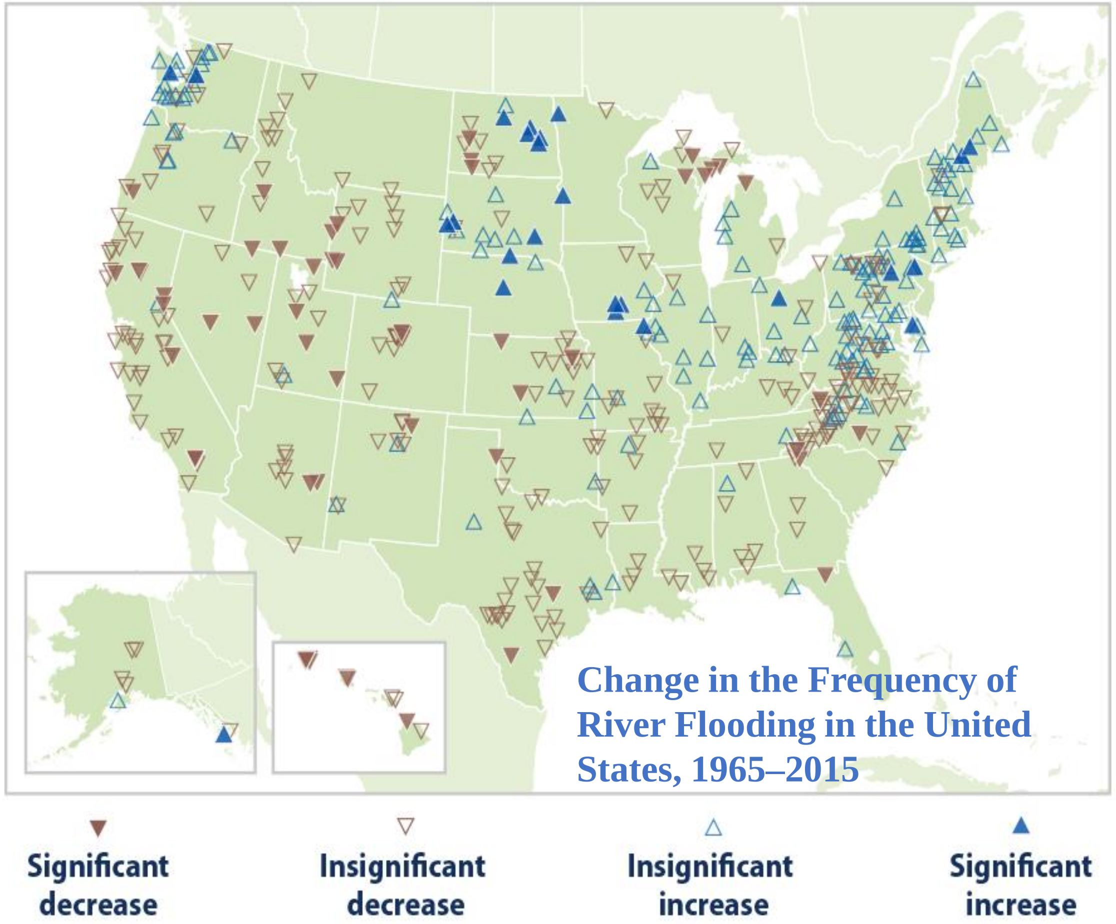
100-yr return flood is projected to happen more frequently in most of the world in 21C than 20C under RCP8.5 scenario with CMIP5 models.



Hirabayashi, 2013, Nature Climate Change

Observed impacts of climate change on flood

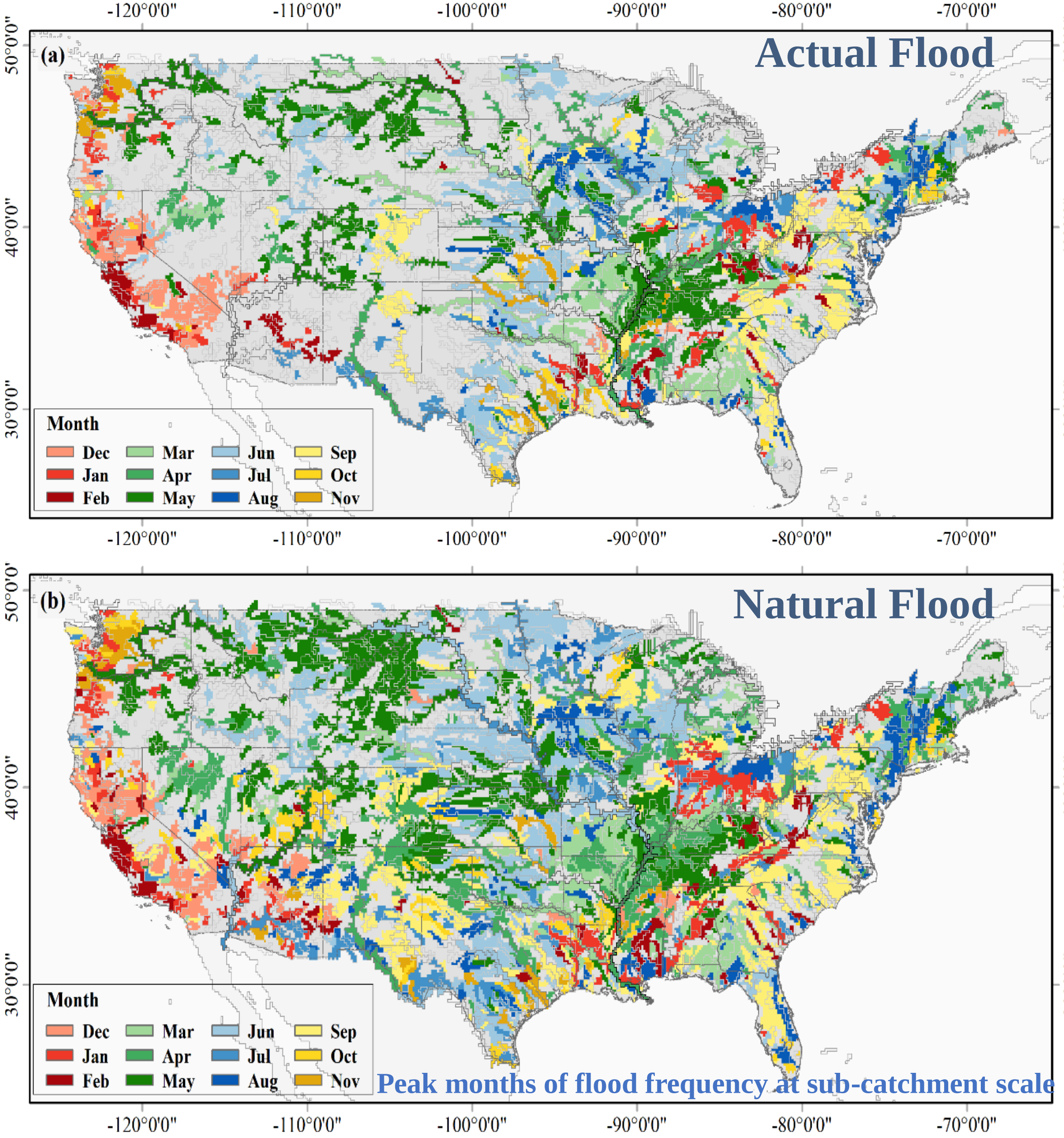




Yet, existing models are ill-suited to provide reliable long-term projections of climate change at the local level.

Slater and Villarini, USGS, 2016

Observed and naturalized flood history at sub-catchment scale



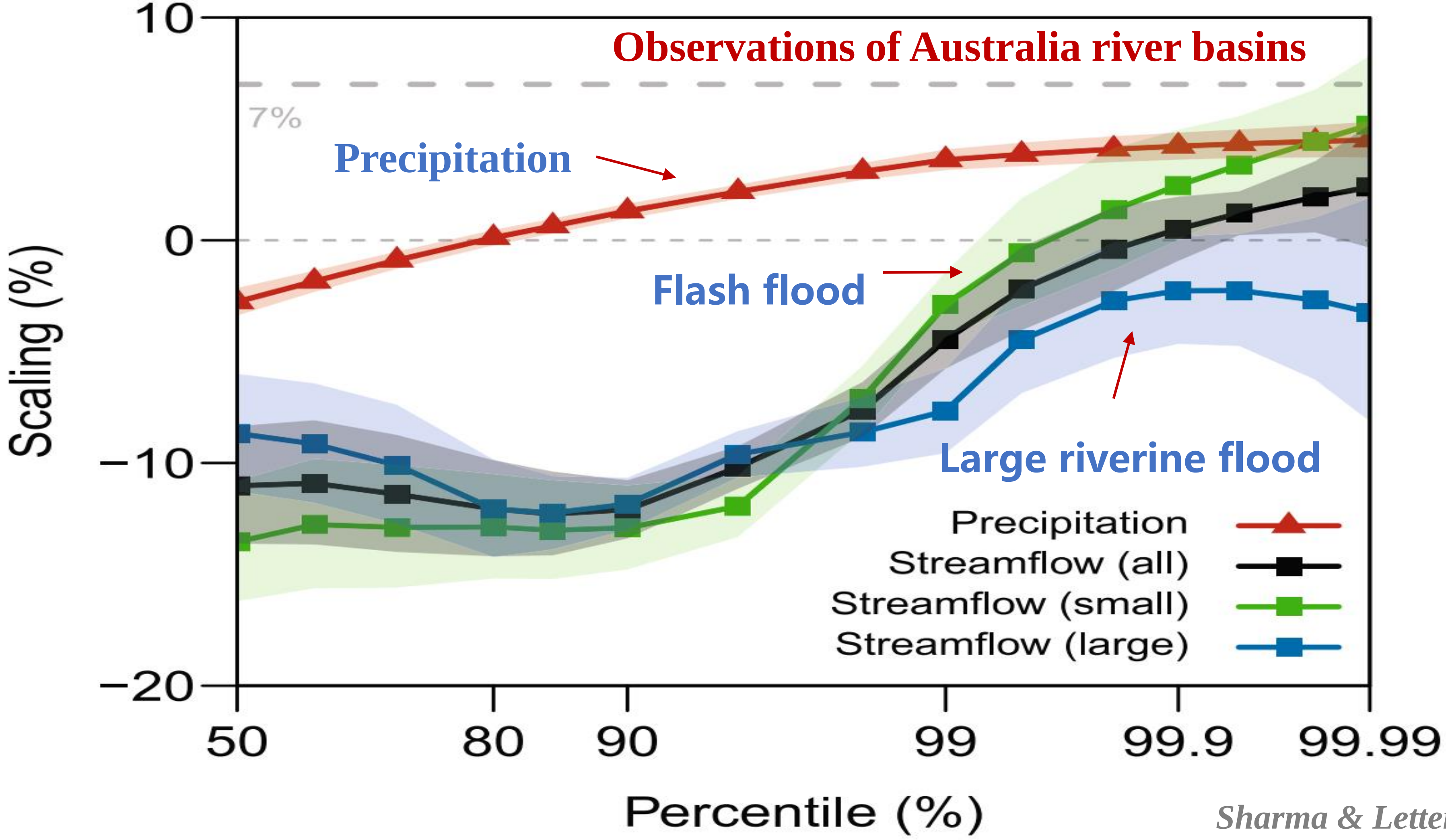
Peak months of flood frequency at sub-catchment scale

- A detailed documentation of significant flood events for each Strahler-order sub-catchment over the CONUS domain during the period of 1998-2013
- Huang & Wu revealed there were 40% (1906) of total 4,661 major flood events (above 20-year return) were muted by flood defense infrastructures and management;

Huang & Wu, BAMS, 2021

Observed impacts of climate change on different type of floods

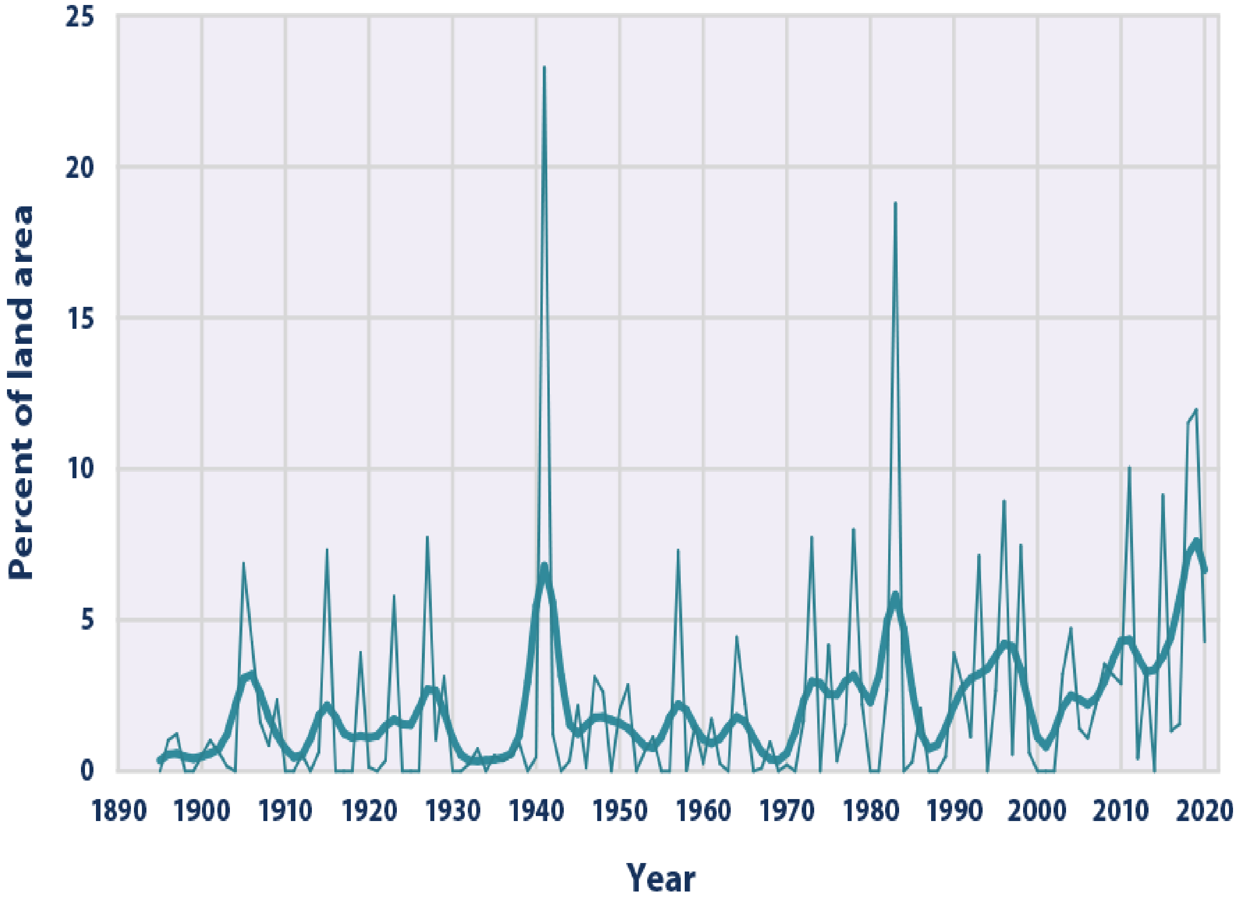
Historic observations show that large riverine floods tend be weaken while small river floods tend to be stronger as responding to increasing precipitation.



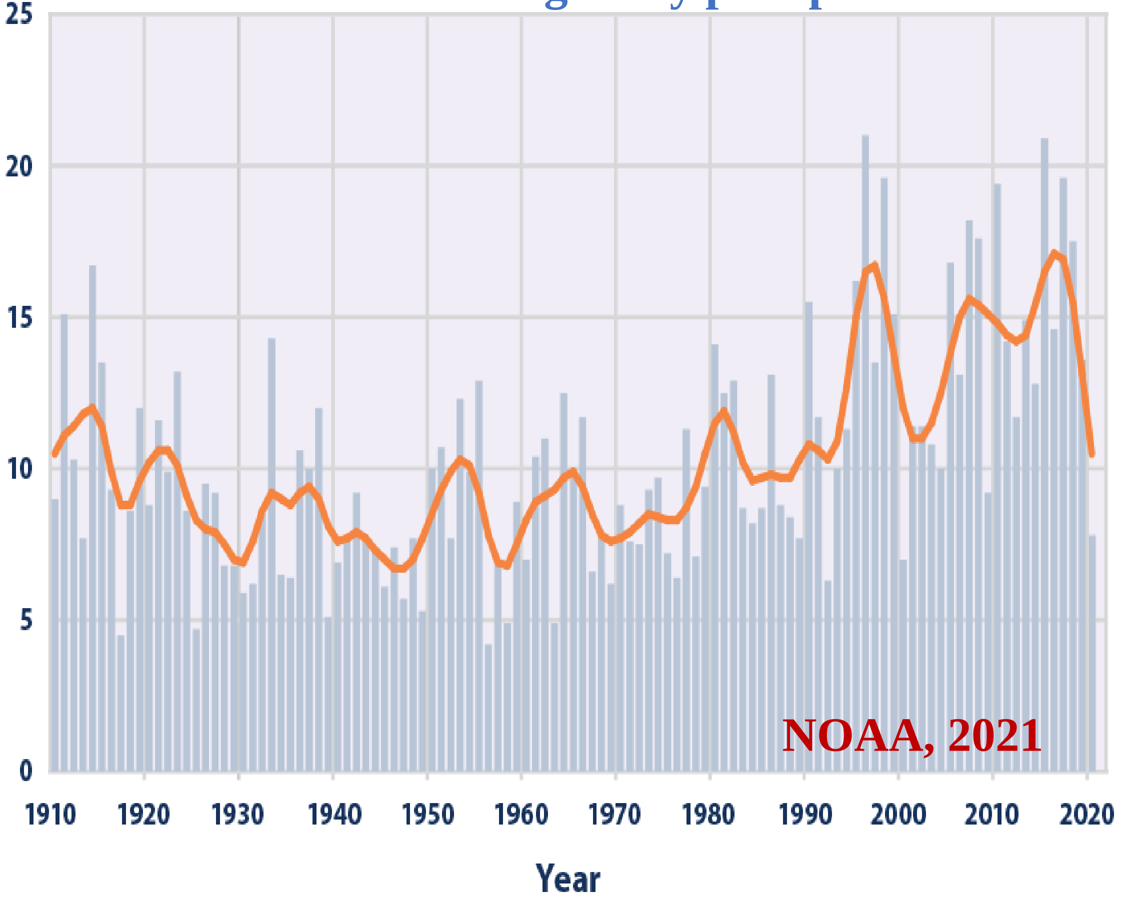
Sharma & Lettenmaier, 2018, WRR

Observed impacts of climate change on flood

The percentage of the CONUS that experienced much greater than normal precipitation

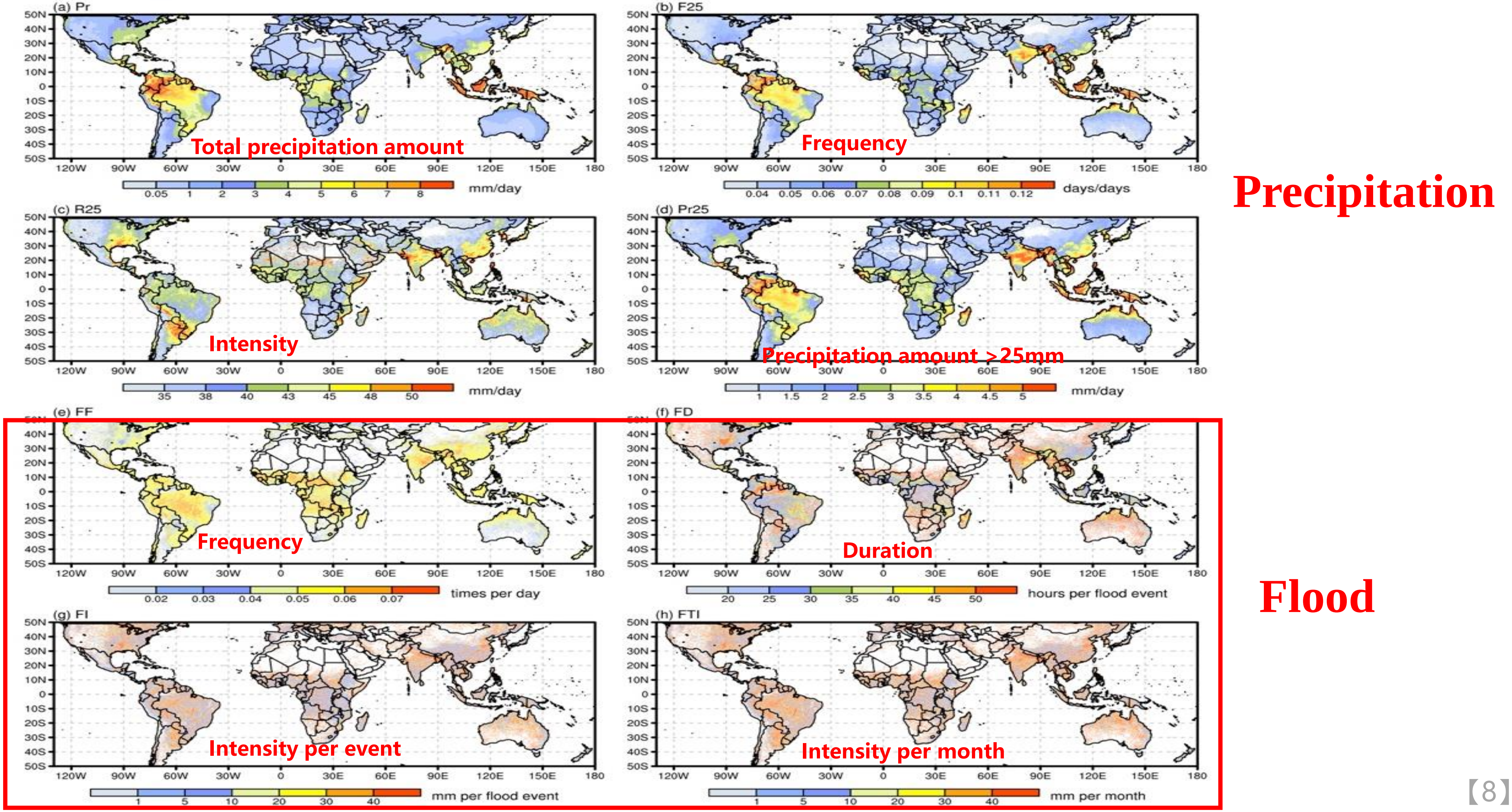


The percentage of the CONUS where a much greater than normal portion of total annual precipitation has come from extreme single-day precipitation events



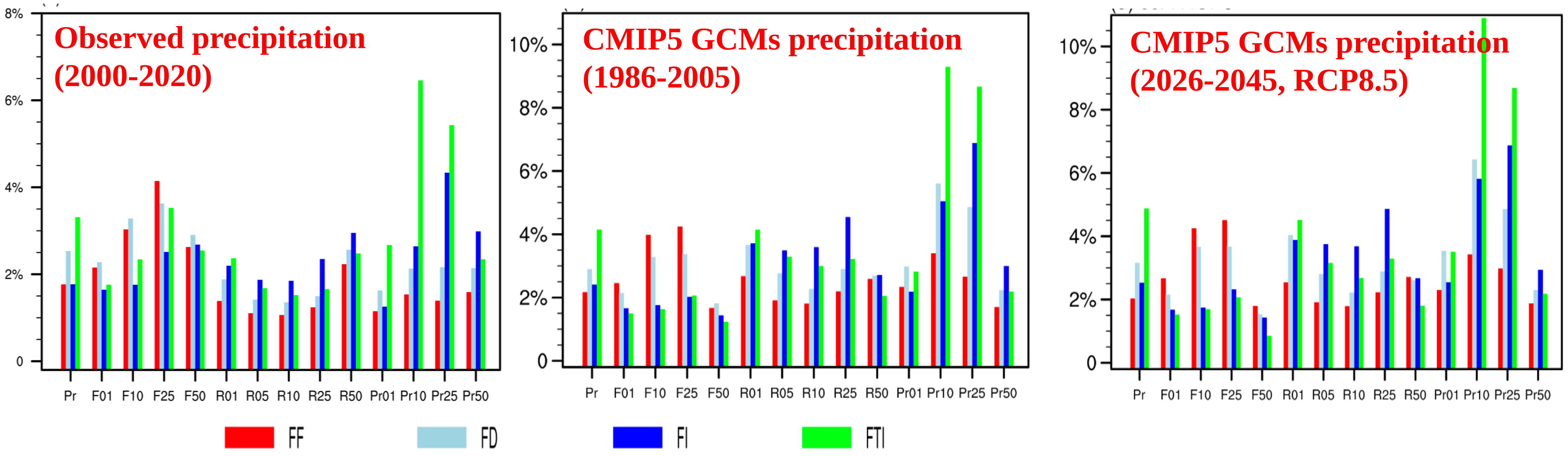
Increases and decreases in frequency and magnitude of river flood events generally coincide with increases and decreases in the frequency of heavy rainfall events

Precipitation-flooding characteristics



Global statistics of precipitation-flood characteristics

The ratios of grids with the largest correlations and the total grids



- **The dominant role of the frequency of extreme precipitation events in the occurrence and duration of of floods.**

- **Flood intensity (FI and FTI) tends to be more associated with total precipitation volume especially for those extreme precipitation events.**

Yan &Wu et al., Journal of Climate, 2020; GRL 2021

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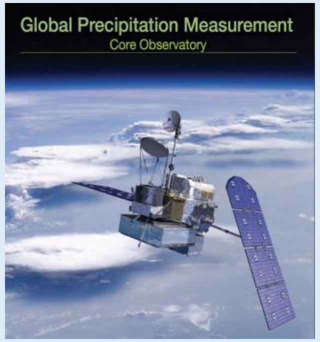
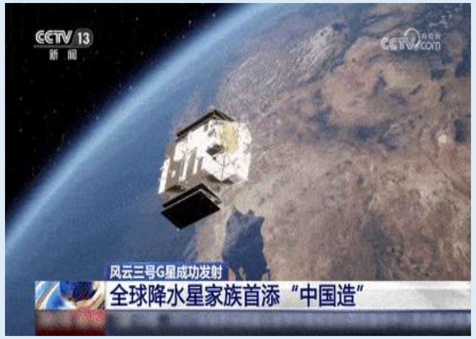
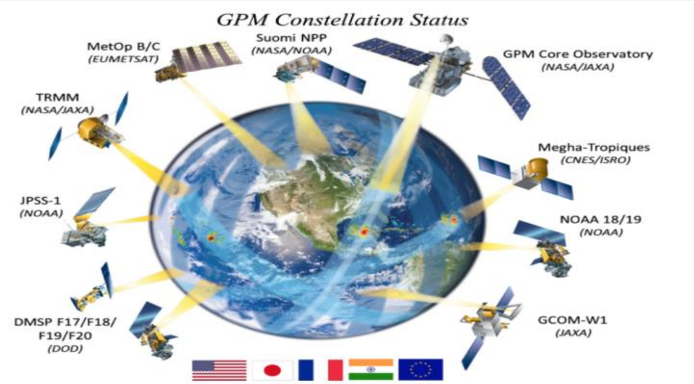
Glocal Hydrometeorological Solution on Floods (GHS-F)

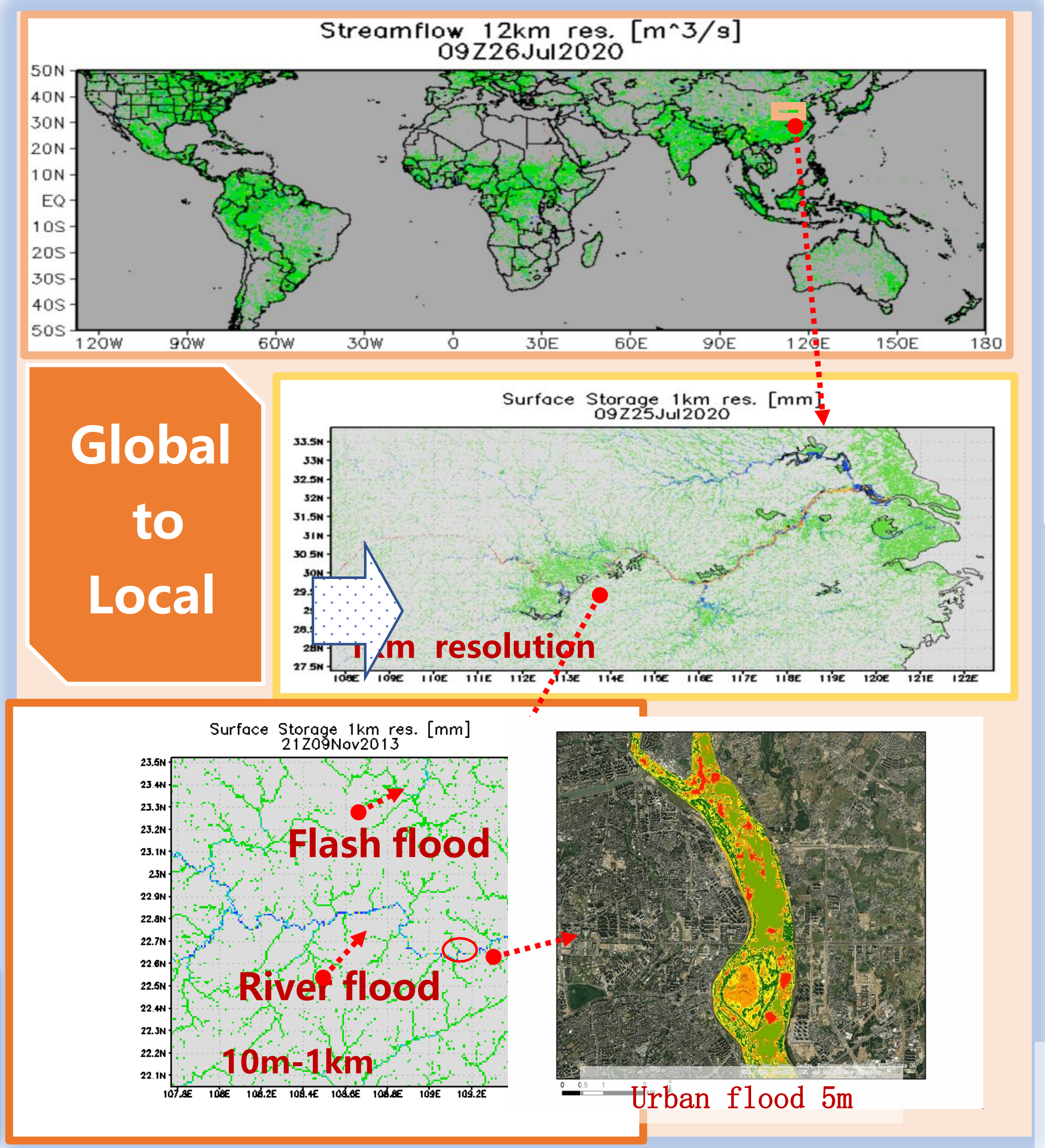
3-hourly, 8th and 1km global flood detection and inundation mapping with hydrological model

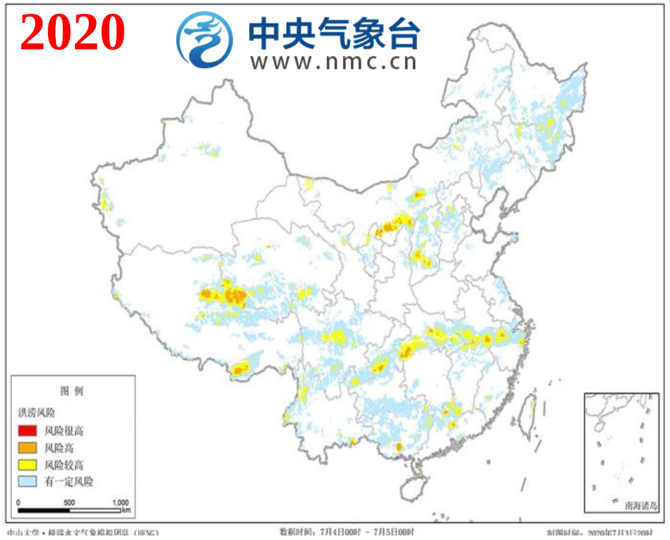


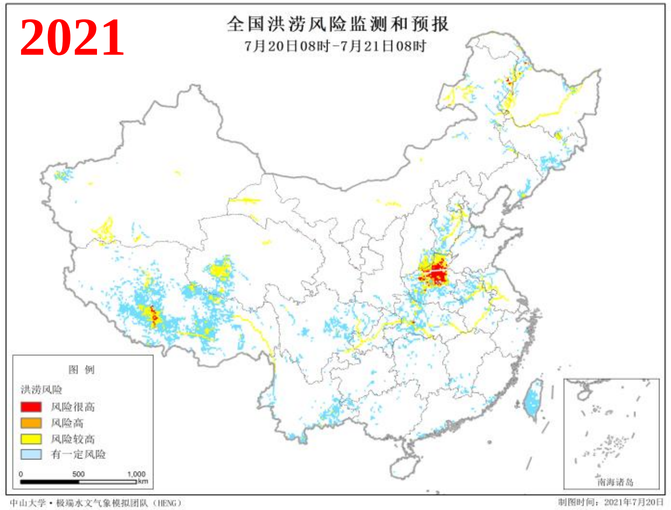




Global Flood Monitoring System (GFMS, Wu et al., 2012, 2014), since 2010

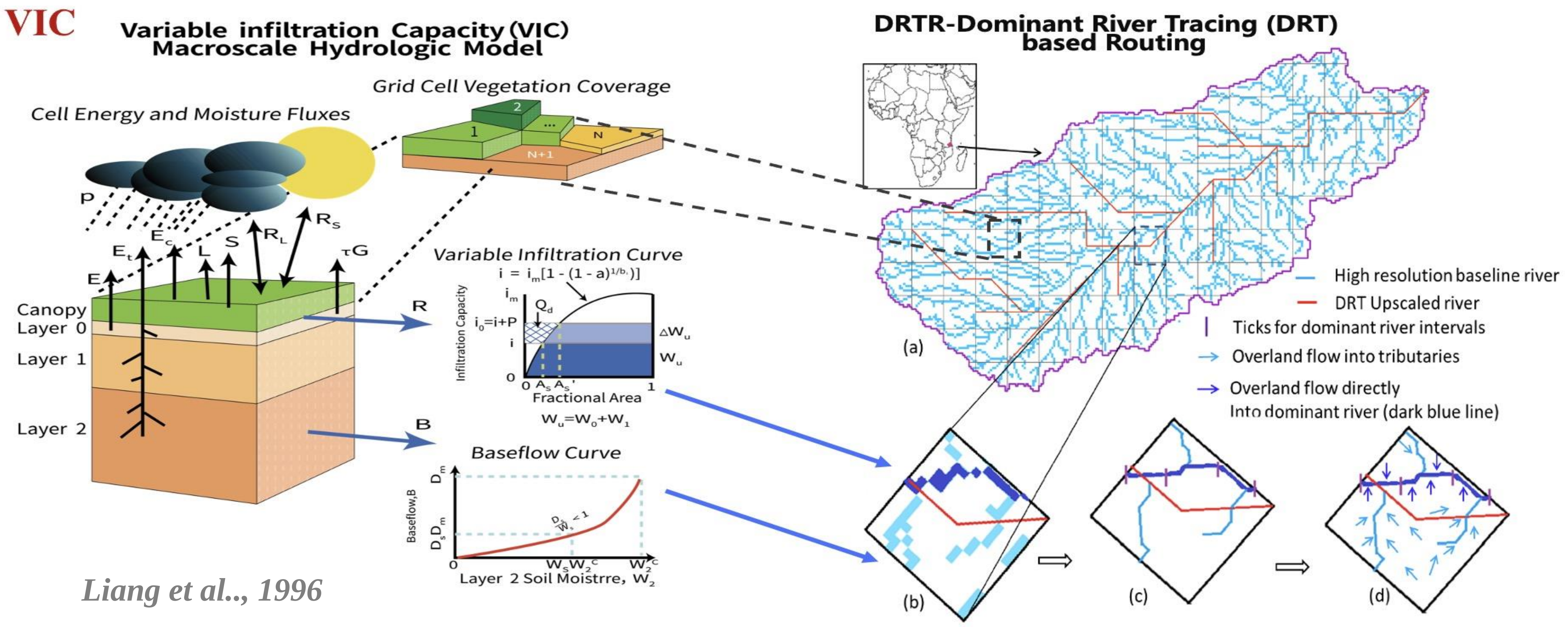






Wu et al., 2011, 2012, 2014;Chen 2022 WRR; 2019 RSE; Huang 2020, BAMS; Wu 2021, AAS; Huang 2023 JHM…

Dominant river tracing-Routing Integrated with VIC Environment (DRIVE) model



Liang et al.., 1996

DRIVE couples runoff generation-routing mechanisms based on the hierarchical dominant drainage network with advanced river basin-grid cell-subgrid parameterization schemes.

Wu et al.., 2012, JHM； Wu et al., 2012， 2014， WRR

Hierarchical dominant river tracing (DRT) based drainage network delineation

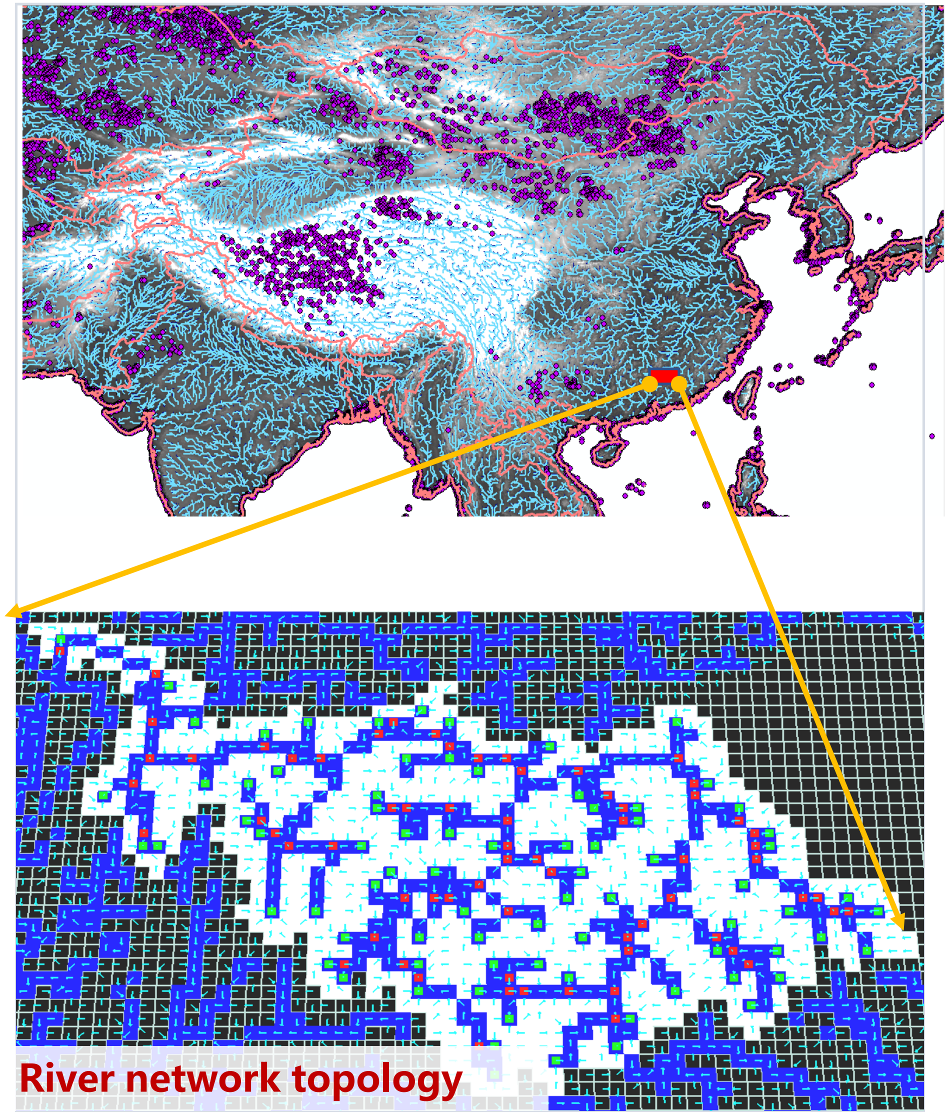
Flow direction, flow distance, slope, flow accumulation area, river width, river basin boundary etc.

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q$$

$$\frac{1}{g}\left(\frac{\partial v}{\partial t} + v\frac{\partial v}{\partial x}\right) + \frac{\partial h}{\partial x} = S_0 - S_f$$

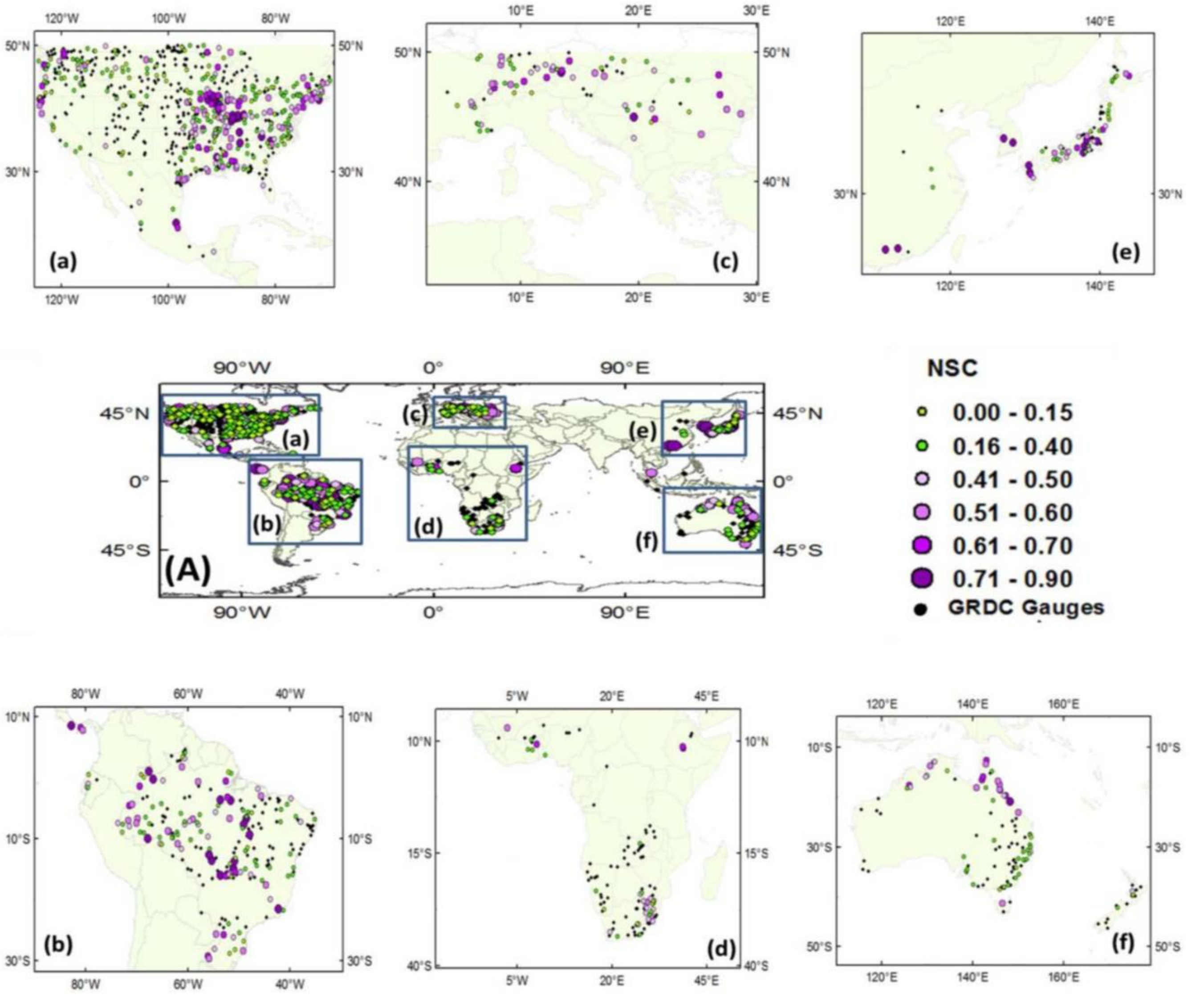
$$v = \frac{1}{n}R^{2/3}S^{1/2}$$

- **DRT derives drainage network with excellent performance in preserving the high resolution DEM information**
- **DRIVE has strong stability and adaptability at various spatial resolutions and scales**

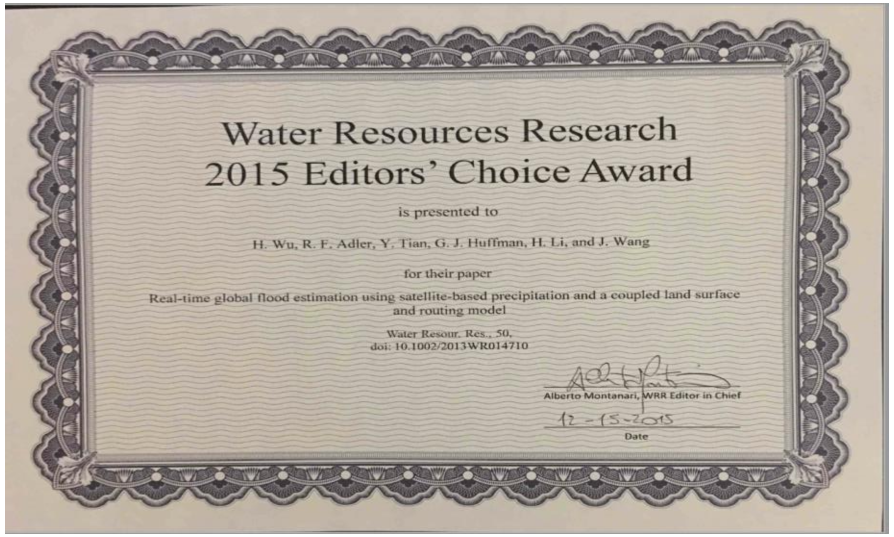


Wu et al., 2011, 2012, WRR

Long-term Evaluation against Streamflow Gauge Observations



DRIVE-RP model performance at 1,121 GRDC streamflow gauges across the globe


Water Resources Research
2015 Editors' Choice Award
is presented to
H. Wu, R. F. Adler, Y. Tian, G. J. Huffman, H. Li, and J. Wang
for their paper
Real-time global flood estimation using satellite-based precipitation and a coupled land surface and routing model
Water Resour. Res., 50, doi: 10.1002/2013WR014710
Alberto Montanari, WRR Editor in Chief
12-15-2015
Date

DRIVE-RP model performance:

Daily: <u>32%</u> of gauges with positive values with mean of 0.22

Monthly: <u>60%</u> of gauges with positive values with mean of 0.39

Wu et al., 2014 WRR

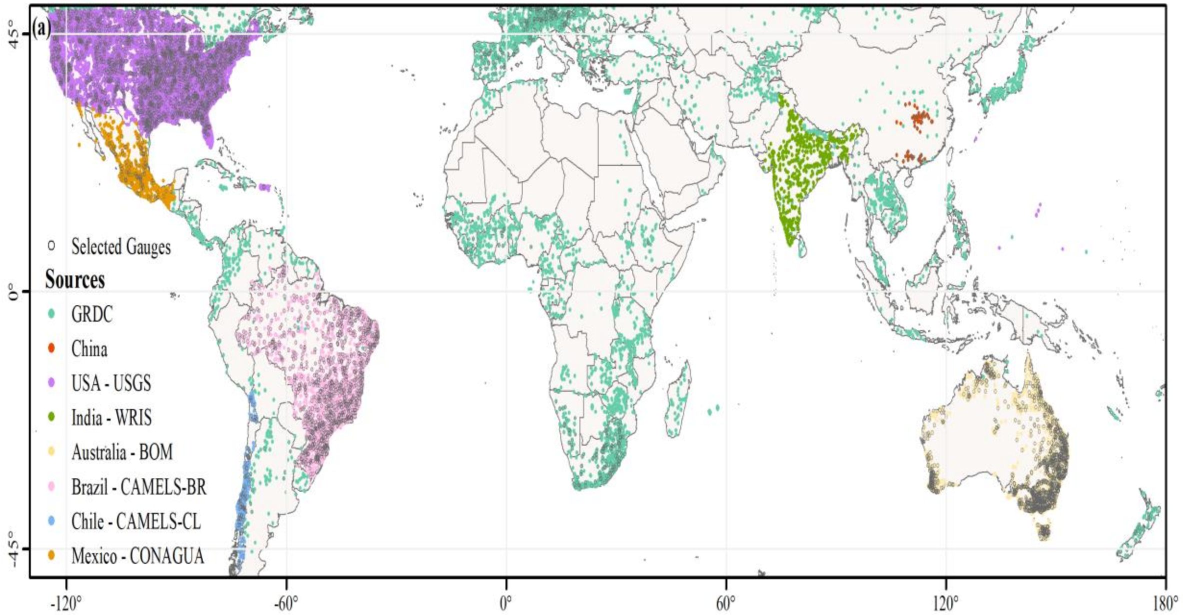
Long-term Evaluation against Streamflow Gauge Observations (2001-2019)

	Simulated Discharge	Daily NSE > 0		Daily R >0.4	
		% of gauges	Mean metrics	% of gauges	Mean metrics
GRDC	DRIVE-F	39.2%	0.30	75.0%	0.62
	DRIVE-RP (Wu et al., 2014)	32.0%	0.22	58.0%	0.57
	DRIVE-E	17.4%	0.24	61.7%	0.58
	DRIVE-RT (Wu et al., 2014)	19.0%	0.16	42.0%	0.53
All Gauges	DRIVE-F	34.0%	0.27	65.8%	0.60
	DRIVE-E	15.9%	0.21	51.5%	0.56
Africa	DRIVE-F	32.9%	0.27	65.8%	0.60
	DRIVE-E	15.5%	0.22	51.6%	0.56
Asia	DRIVE-F	56.8%	0.37	83.2%	0.65
	DRIVE-E	48.9%	0.31	80.0%	0.64
Oceania	DRIVE-F	24.9%	0.20	48.7%	0.54
	DRIVE-E	14.3%	0.14	26.0%	0.52
North America	DRIVE-F	36.6%	0.28	68.9%	0.60
	DRIVE-E	6.8%	0.18	55.9%	0.55
South America	DRIVE-F	41.1%	0.32	80.8%	0.65
	DRIVE-E	32.8%	0.25	75.9%	0.60
Europe	DRIVE-F	21.6%	0.21	78.9%	0.56
	DRIVE-E	11.9%	0.14	60.5%	0.51

IMERG

TMPA

Better performance than described in Wu et al. (2014) that focus on TMPA

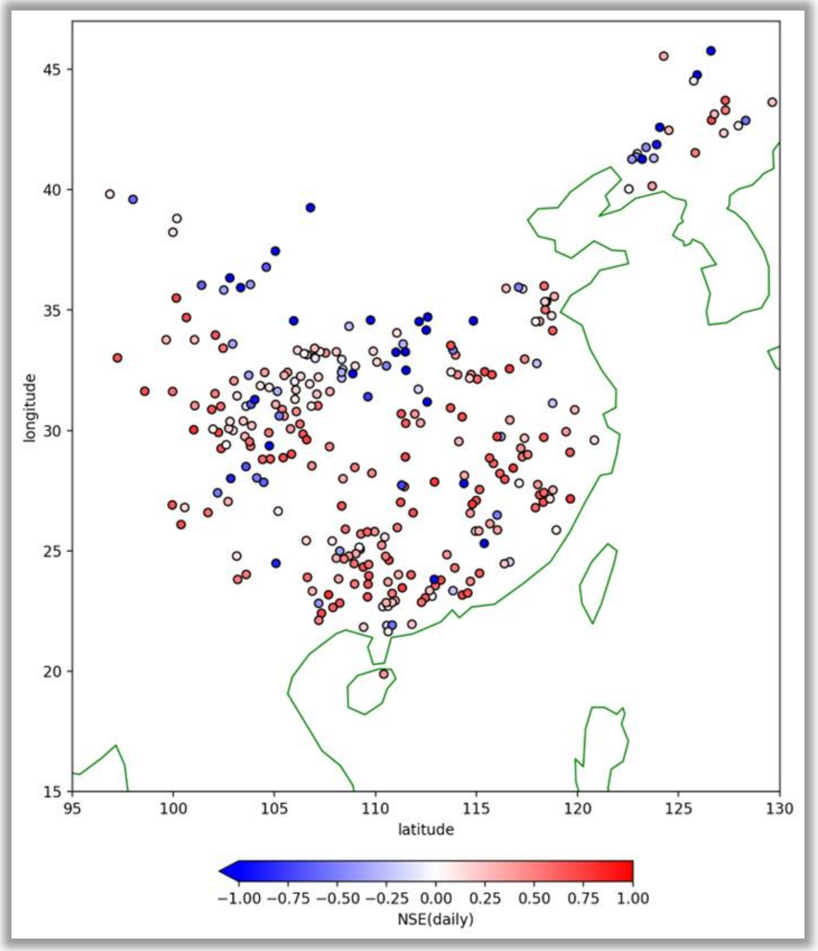


Spatial distribution of 5,828 collected stream gages

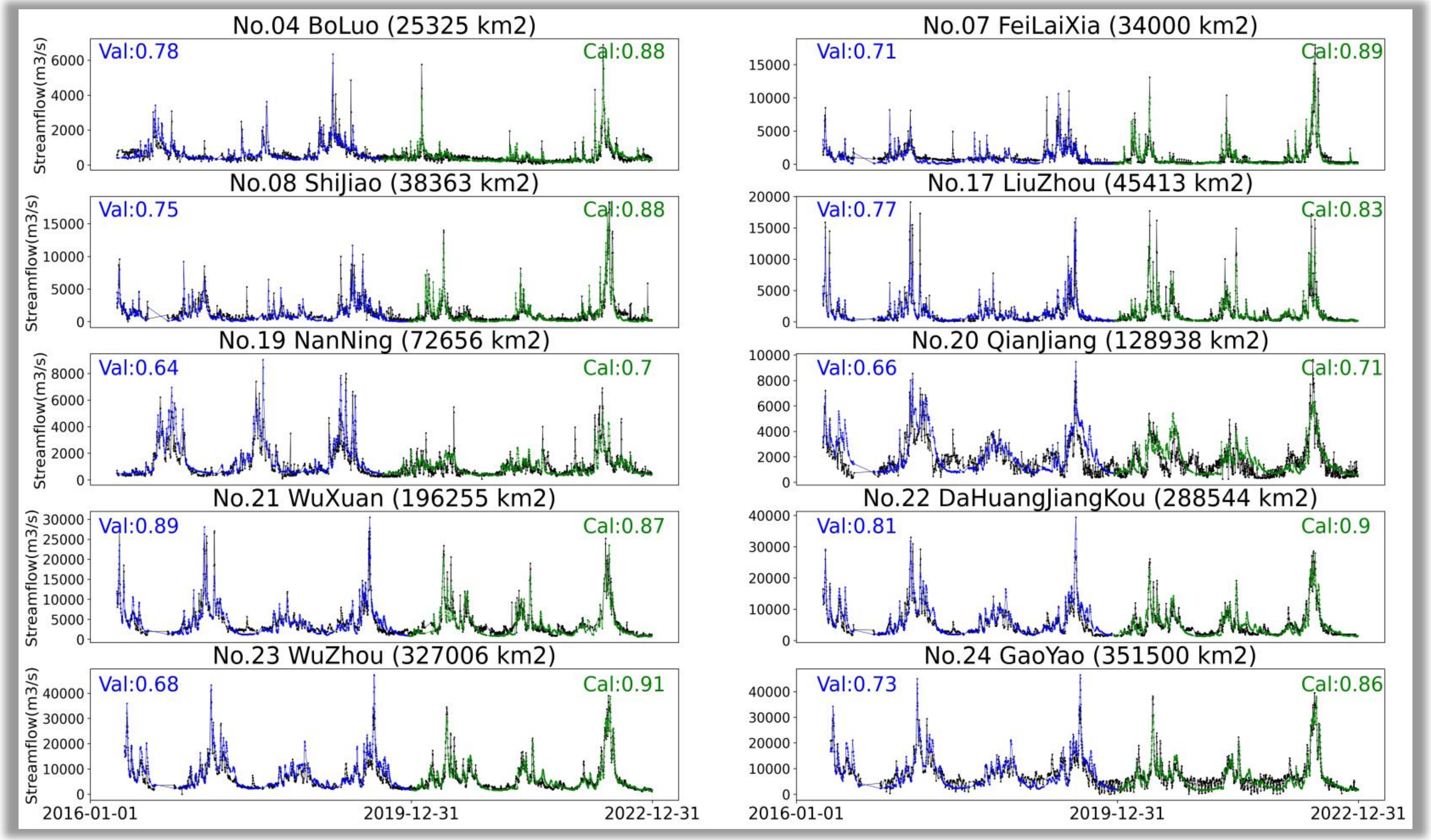
Huang & Wu et al., 2023 JHM

Long-term Evaluation against Streamflow Gauge Observations

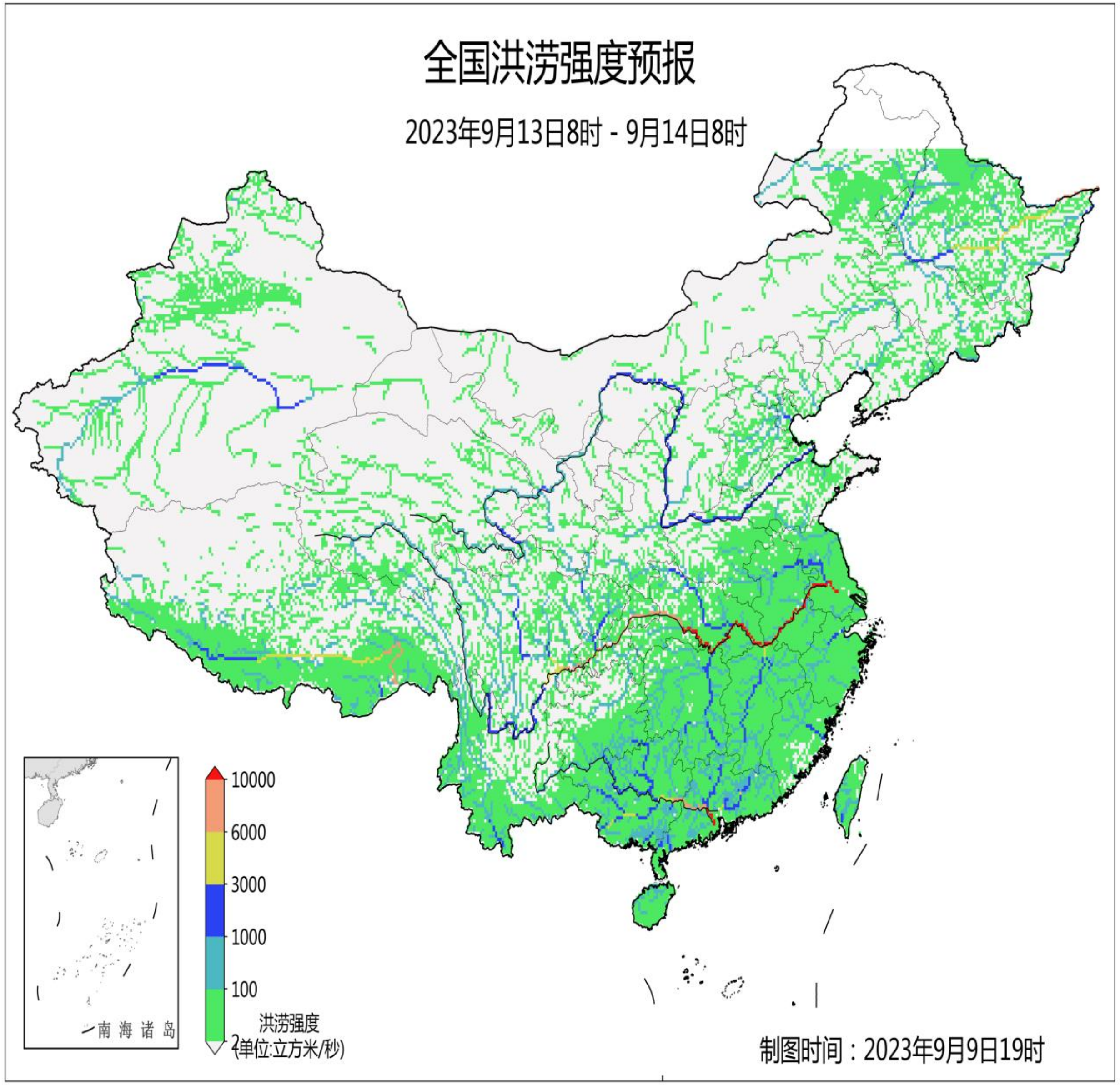
Performed well in most basins

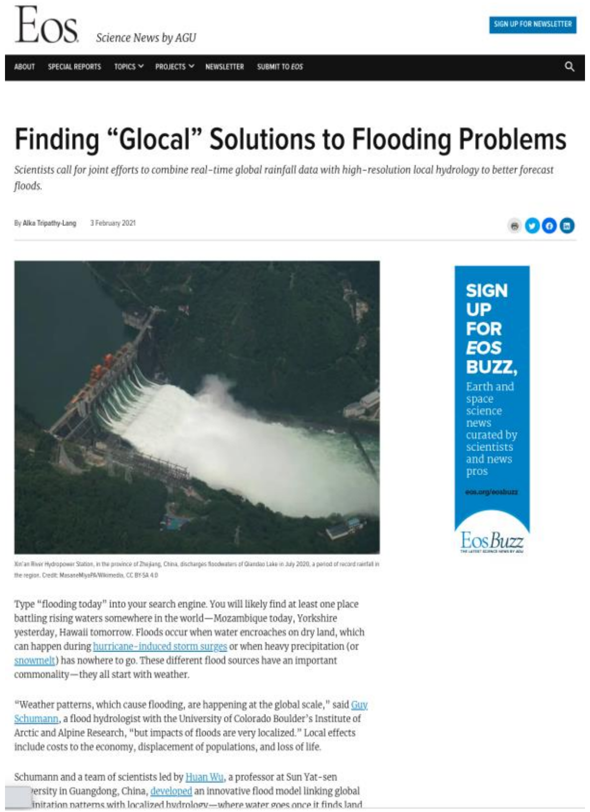


Well captured both flood occurrence and magnitude



GHS-F@China： National to local flood forecasting





Eos Science News by AGU

Finding “Glocal” Solutions to Flooding Problems

Scientists call for joint efforts to combine real-time global rainfall data with high-resolution local hydrology to better forecast floods.

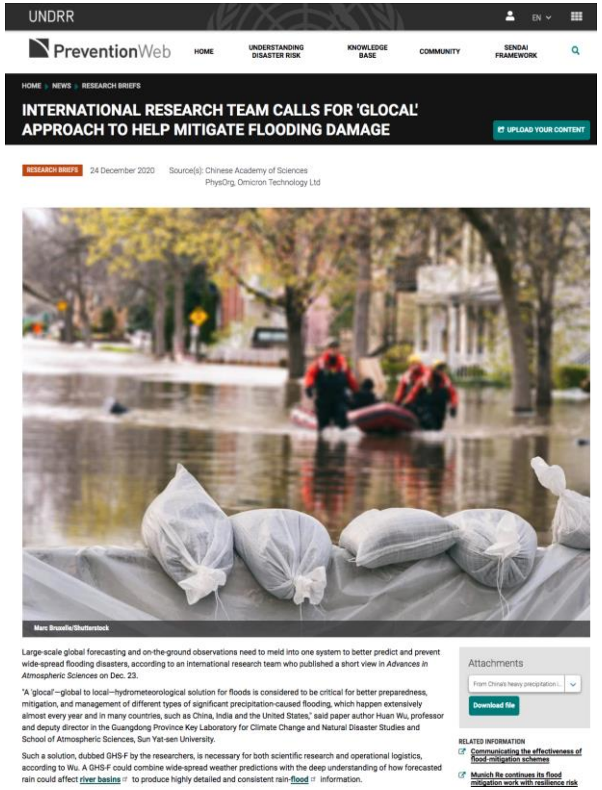
By Alka Tripathy-Lang 3 February 2021

Xin'an River Hydropower Station, in the province of Zhejiang, China, discharges floodwaters of Qiandao Lake in July 2020, a period of record rainfall in the region. Credit: MasaneMiyaPA/Wikimedia, CC BY-SA 4.0

Type “flooding today” into your search engine. You will likely find at least one place battling rising waters somewhere in the world—Mozambique today, Yorkshire yesterday, Hawaii tomorrow. Floods occur when water encroaches on dry land, which can happen during hurricane-induced storm surges or when heavy precipitation (or snowmelt) has nowhere to go. These different flood sources have an important commonality—they all start with weather.

“Weather patterns, which cause flooding, are happening at the global scale,” said Guy Schumann, a flood hydrologist with the University of Colorado Boulder’s Institute of Arctic and Alpine Research, “but impacts of floods are very localized.” Local effects include costs to the economy, displacement of populations, and loss of life.

Schumann and a team of scientists led by Huan Wu, a professor at Sun Yat-sen ...ersity in Guangdong, China, developed an innovative flood model linking global ...



UNDRR PreventionWeb

INTERNATIONAL RESEARCH TEAM CALLS FOR 'GLOCAL' APPROACH TO HELP MITIGATE FLOODING DAMAGE

RESEARCH BRIEFS 24 December 2020 Source(s): Chinese Academy of Sciences, PhysOrg, Omicron Technology Ltd

Marc Bruxelle/Shutterstock

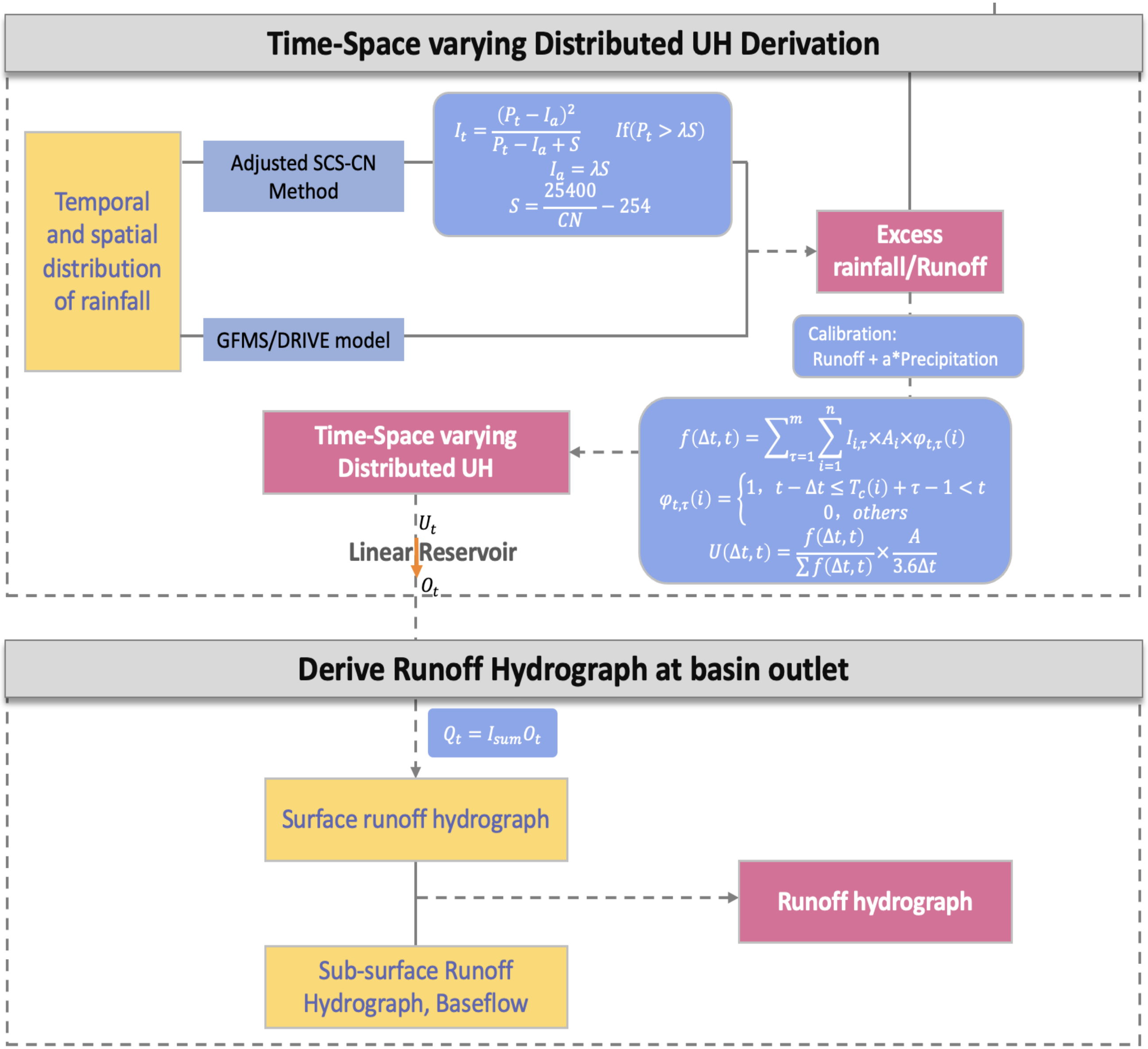
Large-scale global forecasting and on-the-ground observations need to meld into one system to better predict and prevent wide-spread flooding disasters, according to an international research team who published a short view in *Advances in Atmospheric Sciences* on Dec. 23.

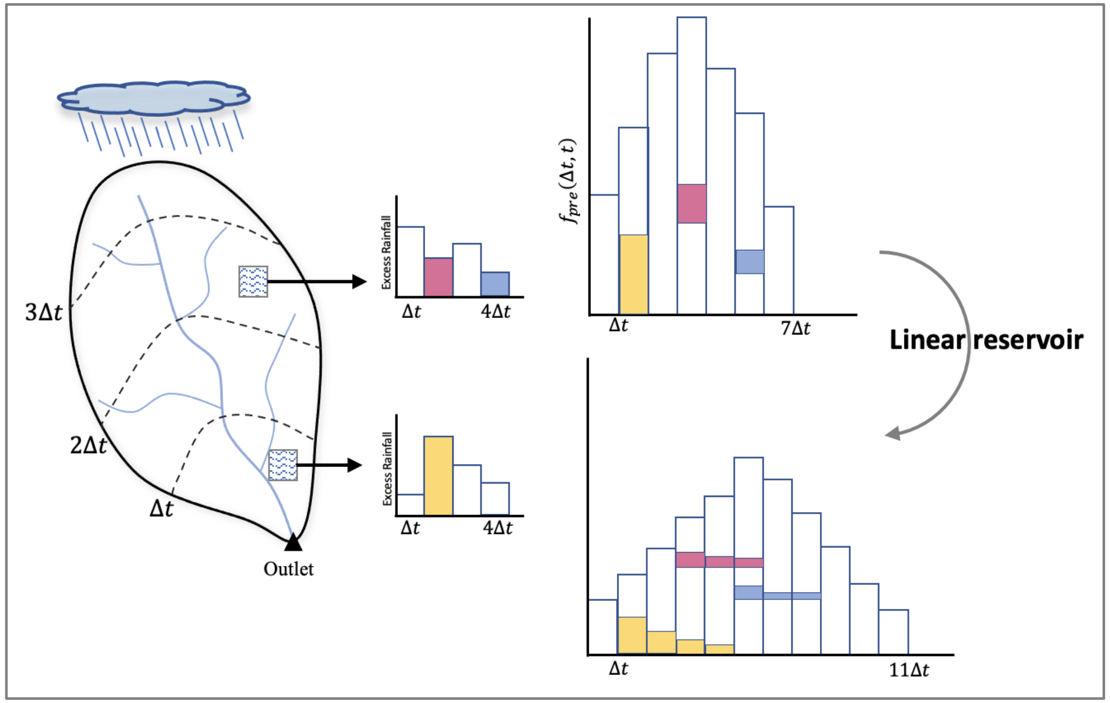
"A 'glocal'—global to local—hydrometeorological solution for floods is considered to be critical for better preparedness, mitigation, and management of different types of significant precipitation-caused flooding, which happen extensively almost every year and in many countries, such as China, India and the United States," said paper author Huan Wu, professor and deputy director in the Guangdong Province Key Laboratory for Climate Change and Natural Disaster Studies and School of Atmospheric Sciences, Sun Yat-sen University.

Such a solution, dubbed GHS-F by the researchers, is necessary for both scientific research and operational logistics, according to Wu. A GHS-F could combine wide-spread weather predictions with the deep understanding of how forecasted rain could affect river basins to produce highly detailed and consistent rain-flood information.

- ➢ **Flash flooding**
- ➢ **Urban flooding**

A Time-Space varying Distributed Unit Hydrograph(TS-DUH)



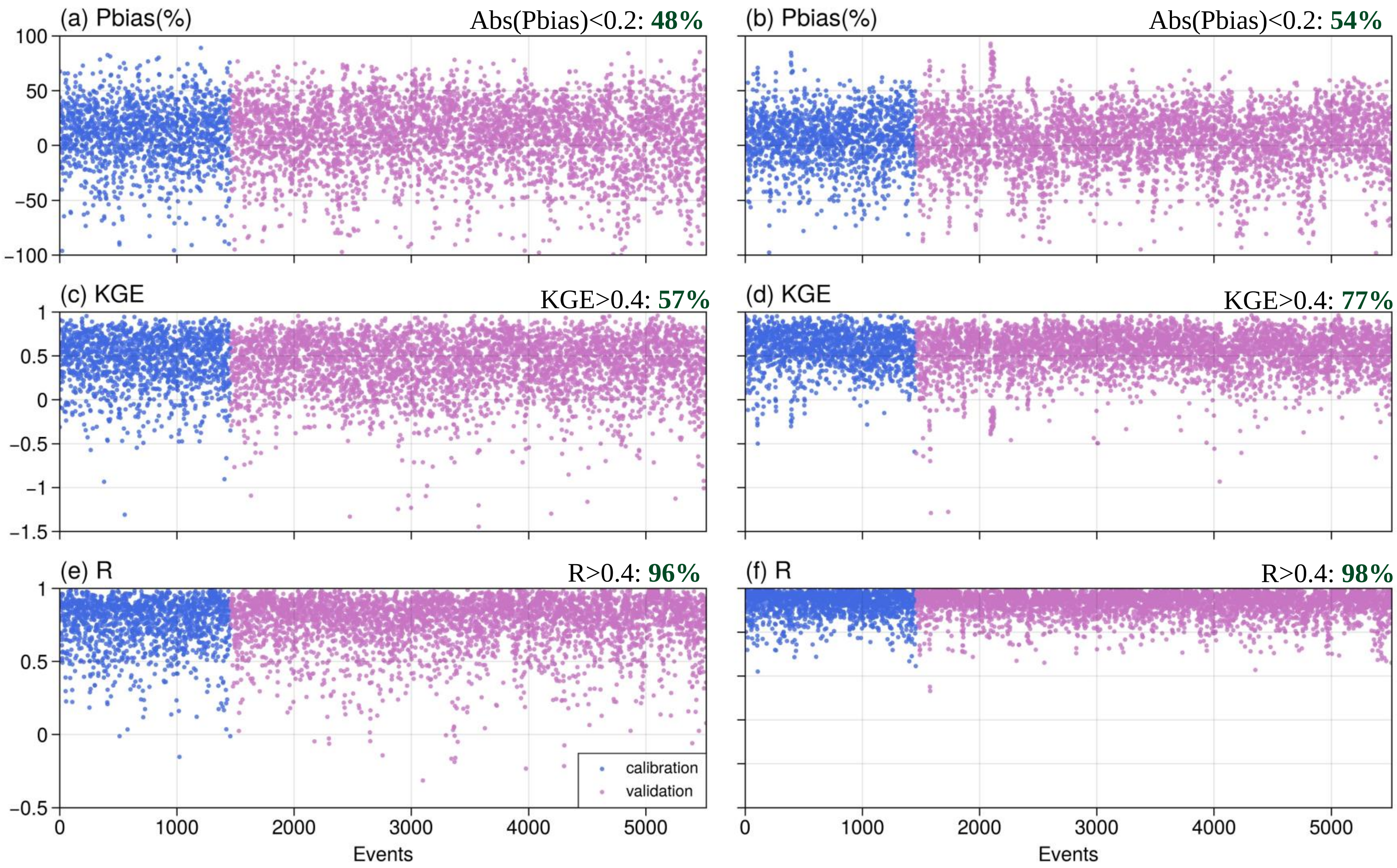


- Considering **the heterogeneous and dynamic runoff contribution** caused by rainfall and soil moisture variations
- Two runoff methods: **the adjusted SCS-CN** method and the **DRIVE-Runoff** output by the DRIVE model

Hu & Wu, in prep.

Event-based flash flood discharge simulation skill assessment

CN-TS-DUH | **DRIVE-TS-DUH**



Precipitation：NLDAS-2

Runoff yield：SCS-CN Vs. DRIVE-Runoff

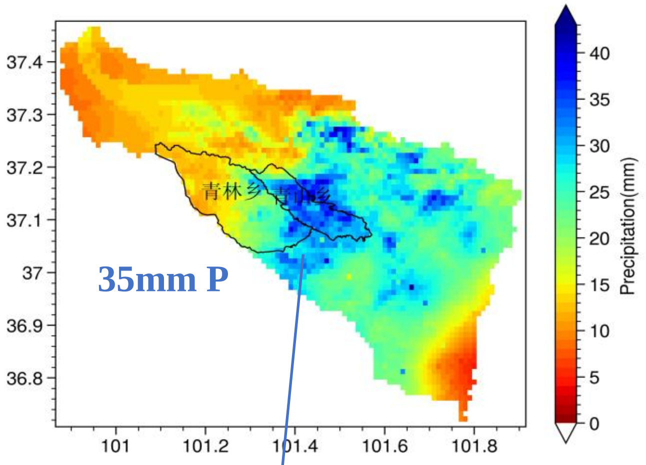
Flow routing：TS-DUH

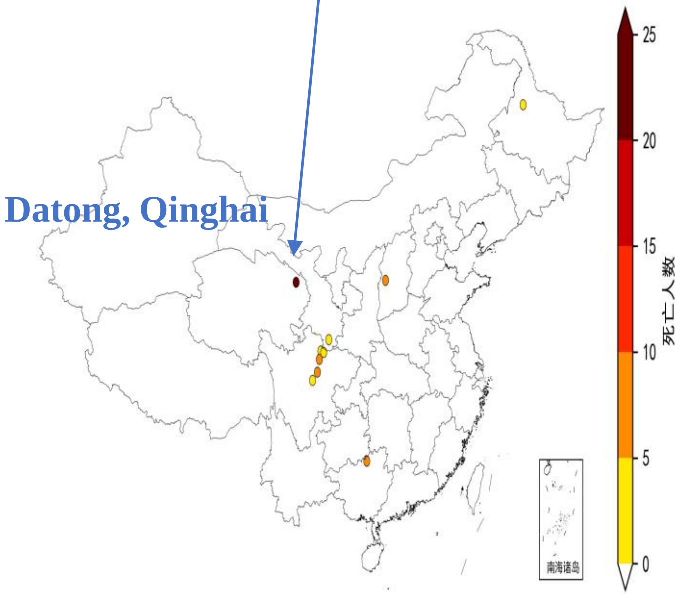
Time step : 1h

- 5,517 flash flood events at 243 stations (1985-2016)
- Six events per station are randomly selected for calibration
- POD:
  SCS-CN ~ 0.8
  DRIVE-Runoff ~ 0.9

Hu & Wu, in prep.

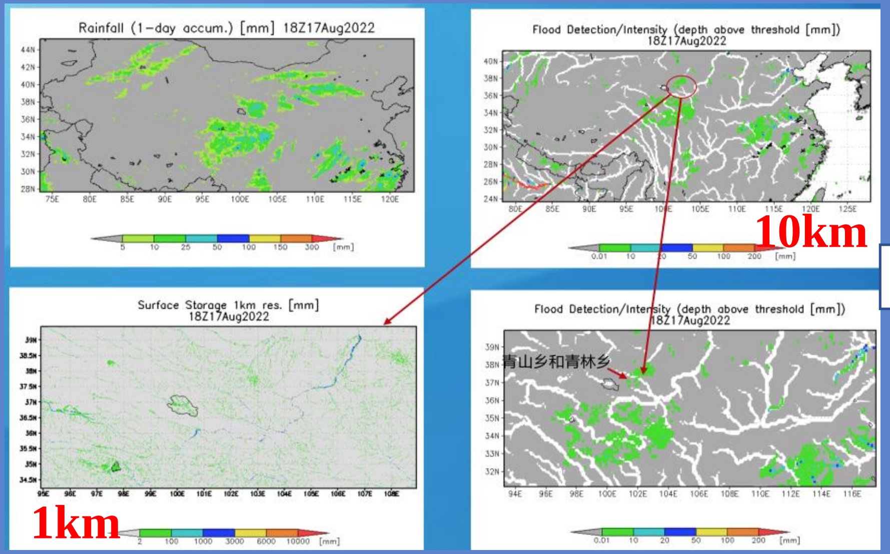
Case 2: Local scale (Flash) flooding, Aug. 18, 2022

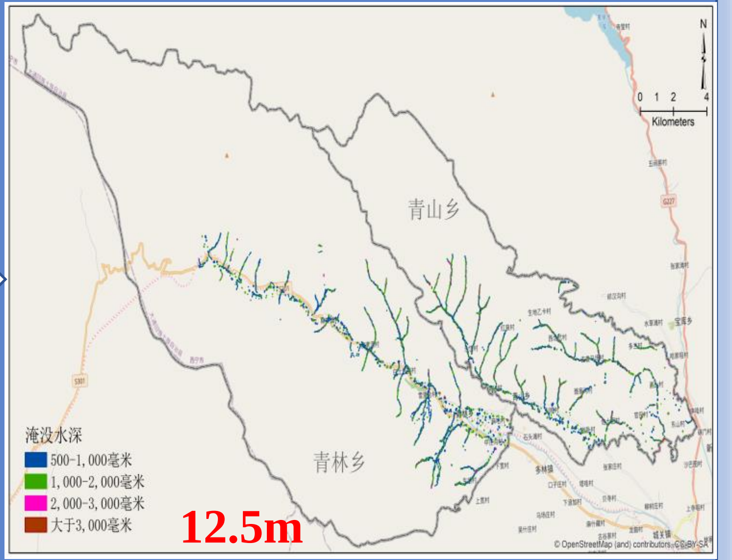




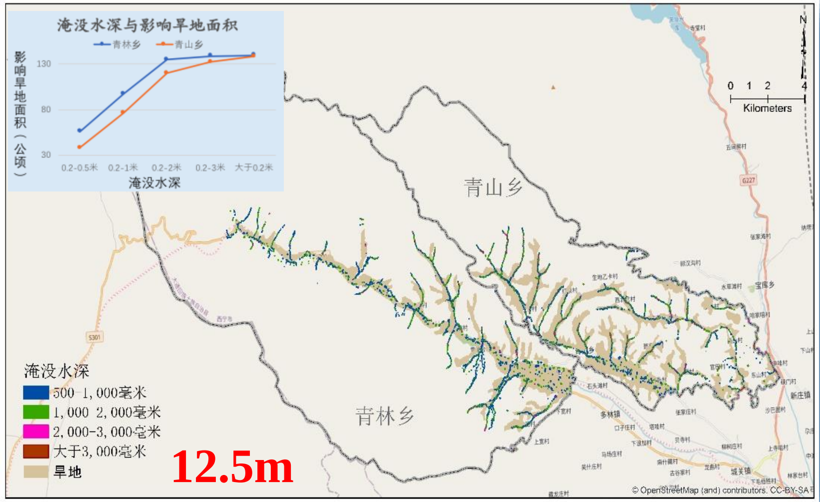
Datong, Qinghai

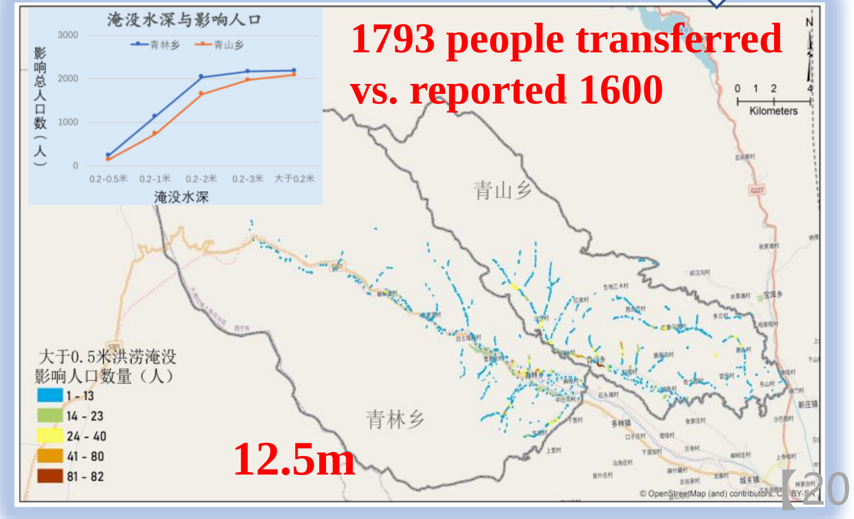
31 people loss





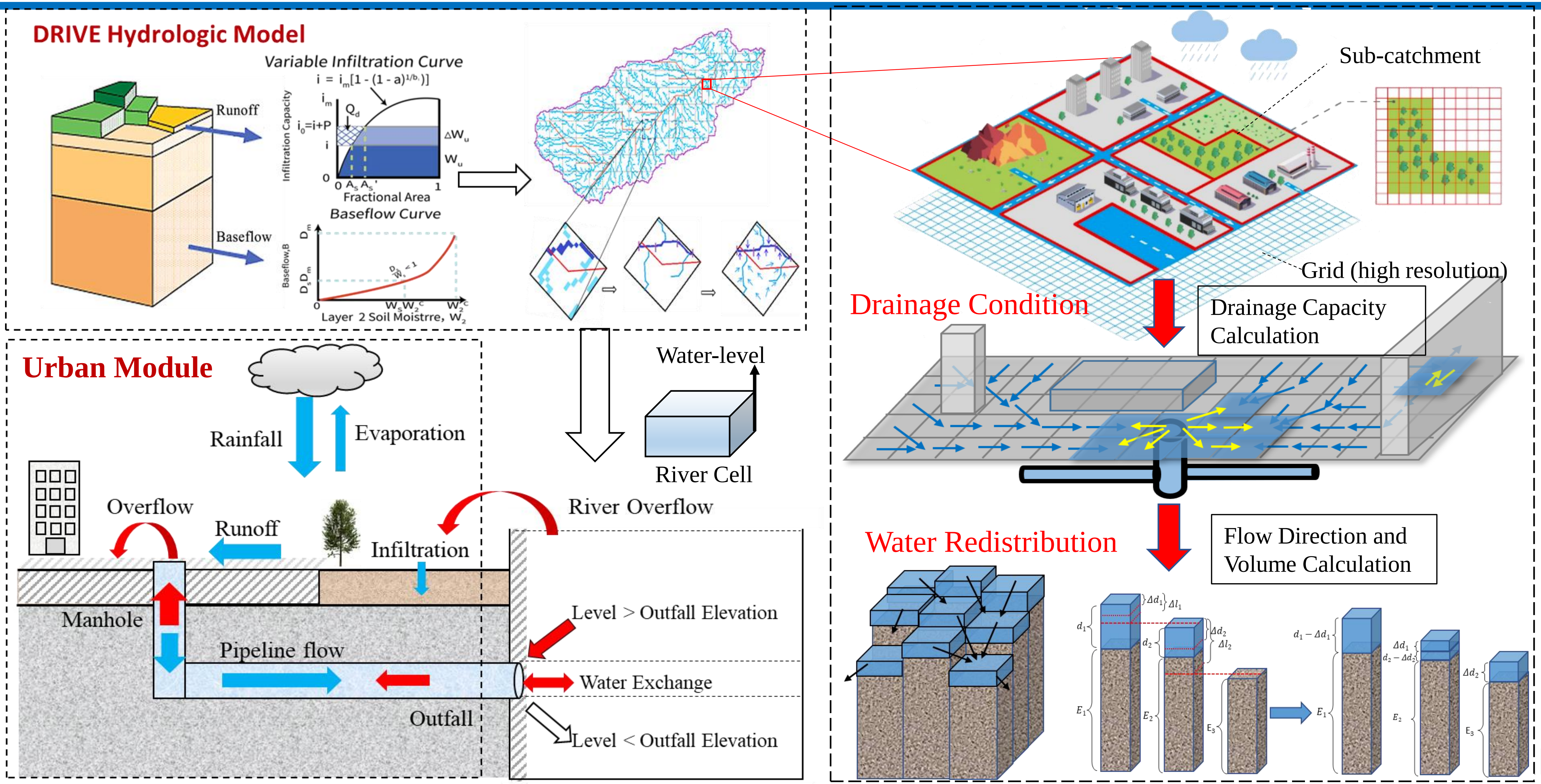
Global Hydrodynamic downscaling to Local



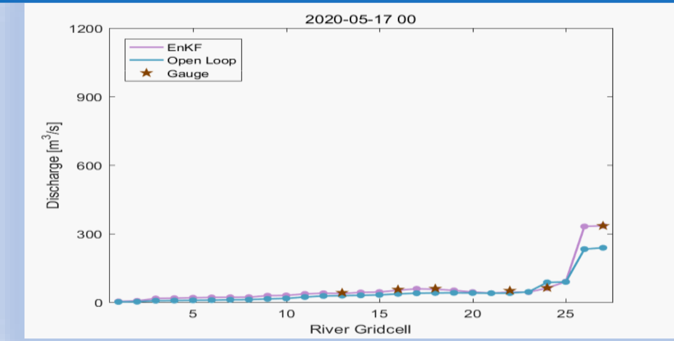


1793 people transferred vs. reported 1600

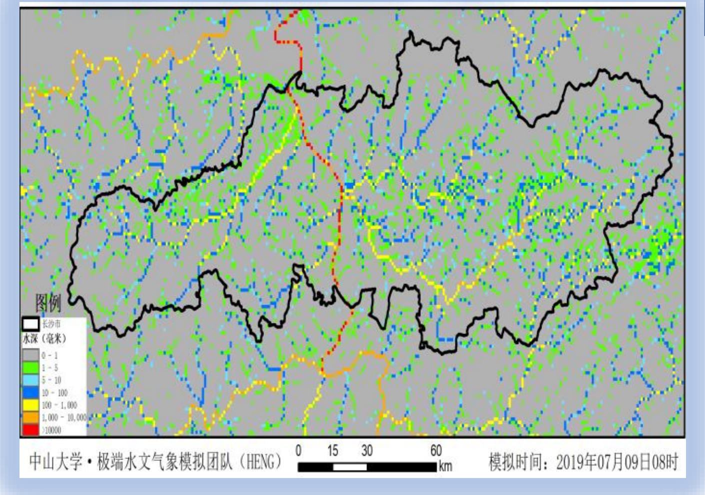
DRIVE-Urban: coupled river basin-urban hydrological and hydraulic modeling

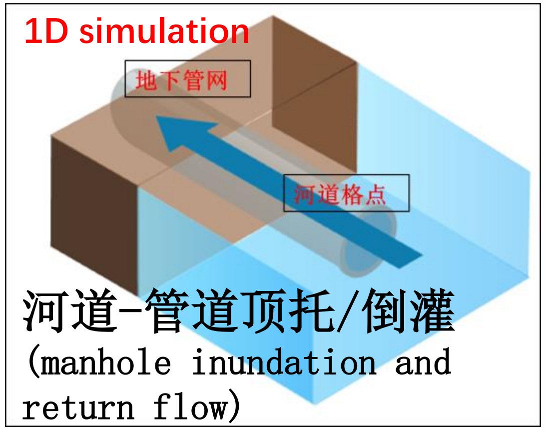


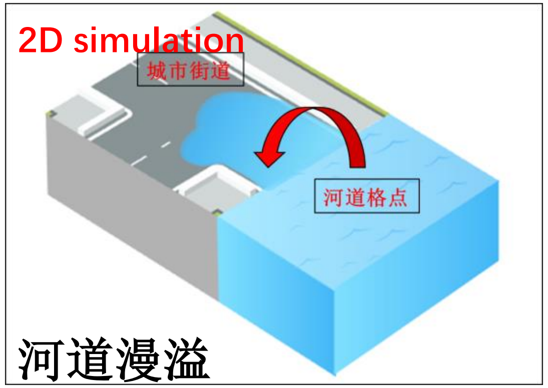
Real-time streamflow assimilation for better fluvial-urban coupled flood monitoring and forecasting



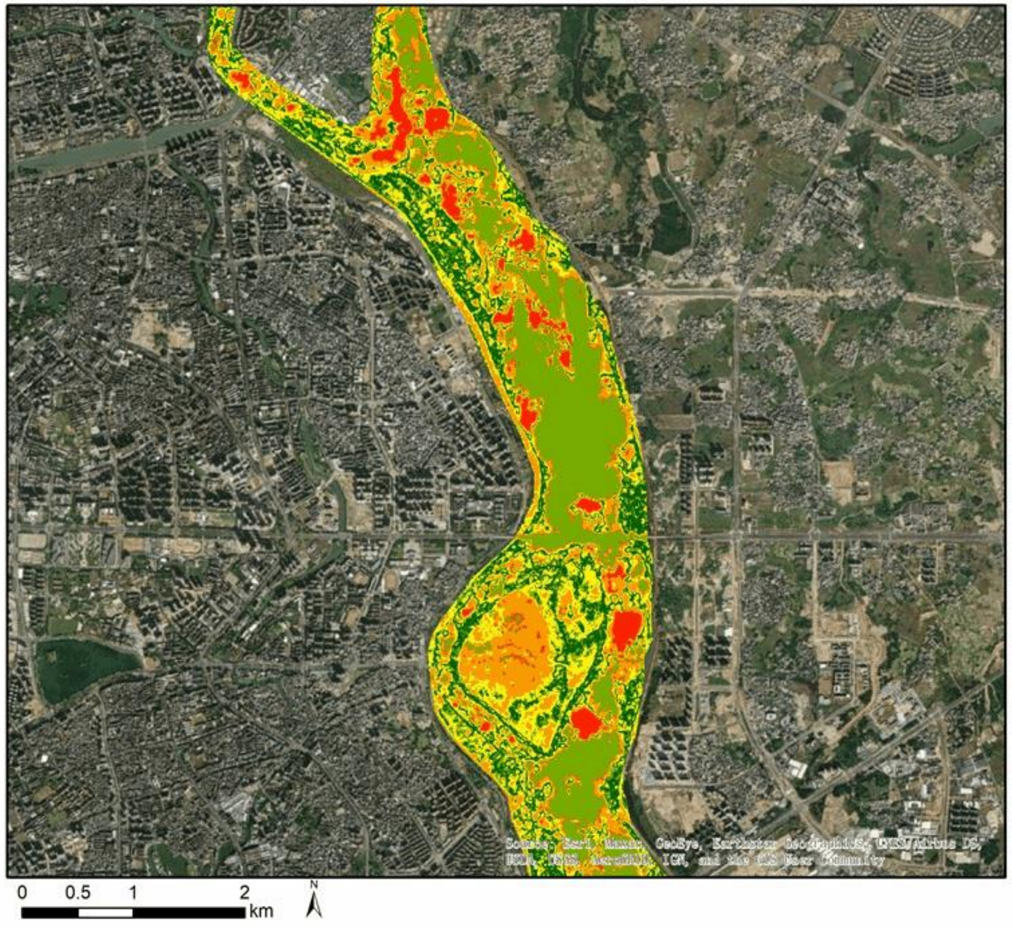
流域实时径流同化(river flow assimilation)







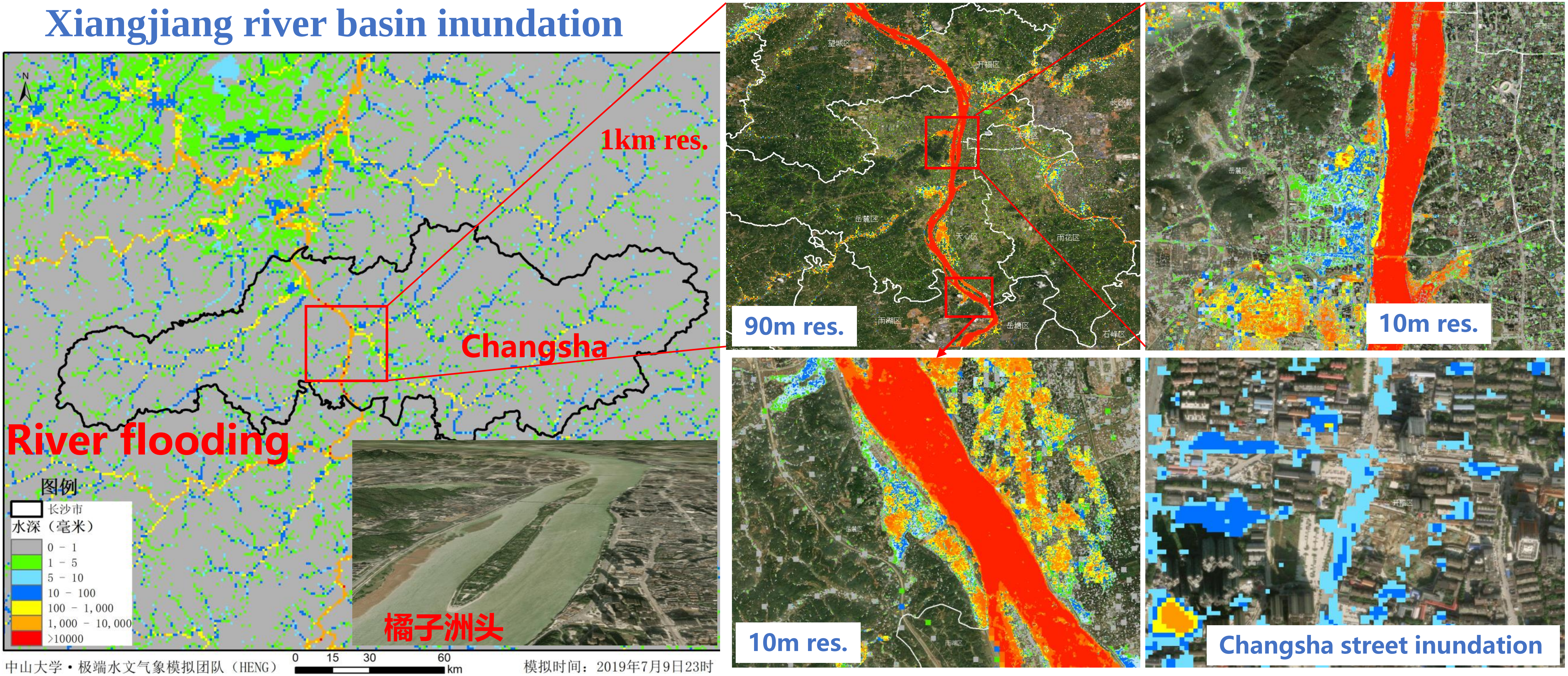
(River overbank flow)



With assimilating real-time upstream river stage observations, the DRIVE-urban model provides accurate downstream water level for modeling of river overbank flow inundation and manhole return water inundation, which allows for detailed and reliable street inundation mapping.

Local catchment-street level: fluvial-pluvial flood risk forecasting

Xiangjiang river basin inundation



Chen & Wu* et al., 2022, WRR

Validations show very good performance in both fluvial and pluvial flood modeling with POD of stream segment inundation>70%

Summary

- **Multi-scale floods (Flash flood, Riverine flood and Urban flood) need to and can be well addressed in one modeling framework for better risk estimation and response under the warming climate;**
- **The DRIVE model based Glocal Hydrometeorological Solution on Floods (GHS-F) has been working with good applications from global to local scales, indicating pathways for further improvement;**
- **Challenges ahead mainly lie in fundamental datasets: precipitation, DEM etc.**

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Thanks