Global to Local Flood Monitoring and Forecasting

Huan Wu（吴欢）

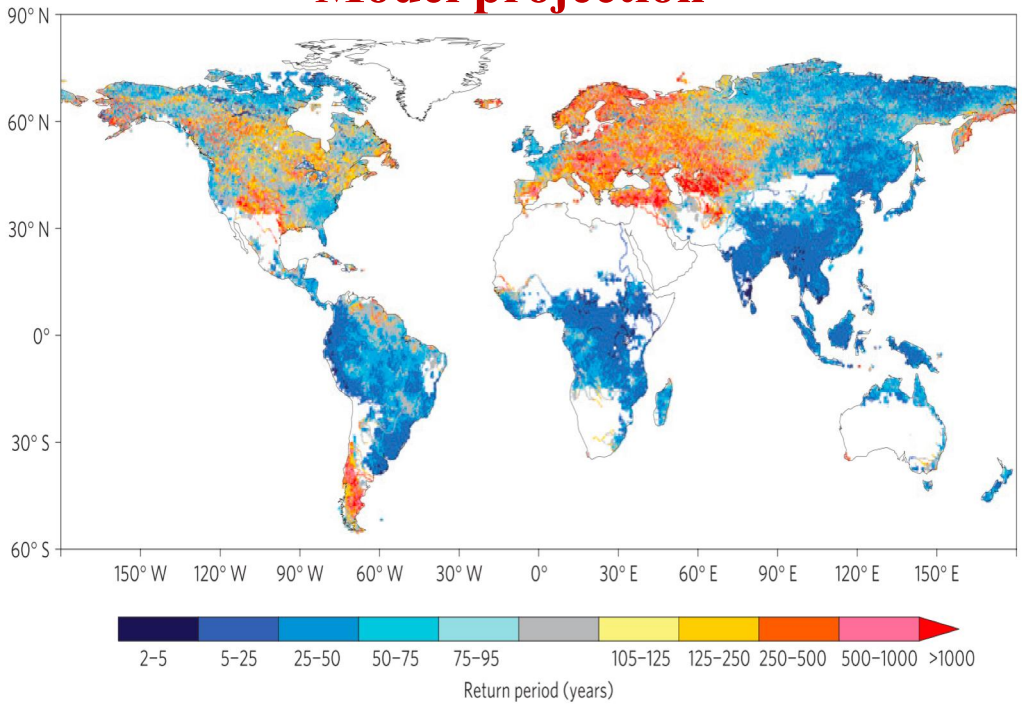
Hydrometeorological Extremes simulatioN Group (HENG),
School of Atmospheric Sciences, Sun Yat-sen University (SYSU)

Impacts of climate change on flood

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

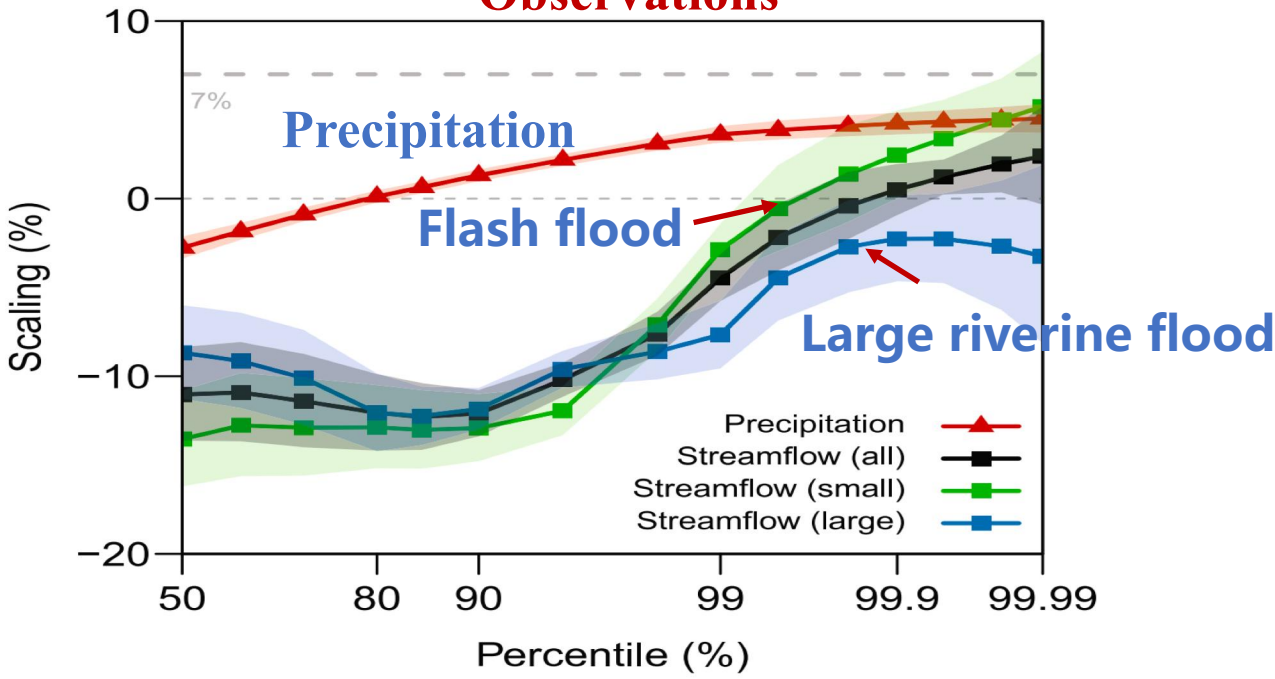
- Historic observations show that large riverine floods tend be weaken while small river floods tend to be stronger as responding to increasing precipitation.

Model projection



Hirabayashi, 2013, Nature Climate Change

Observations



Sharma & Lettenmaier, 2018, WRR

HENG
Hydrometeorological Extremes simulatioN Group

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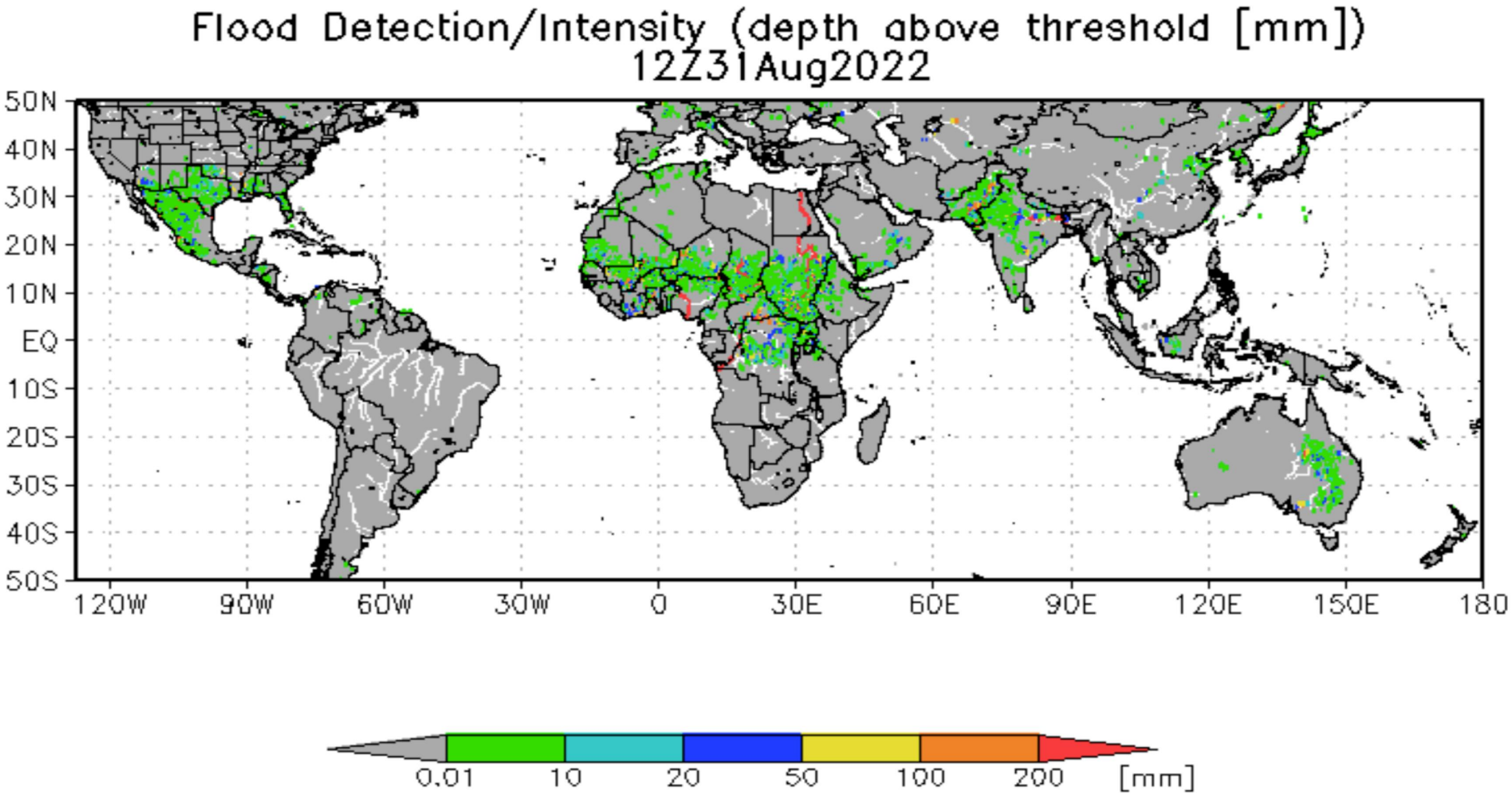
- The DRIVE model
- Global Flood Monitoring System (GFMS)
- Glocal Hydrometeorological Solution on Floods (GHS-F)

This moment's world flood situation …



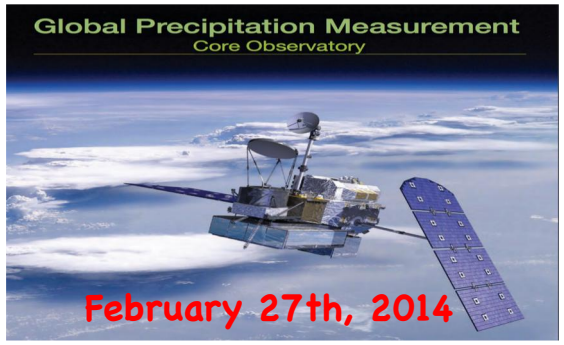
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION | GODDARD SPACE FLIGHT CENTER

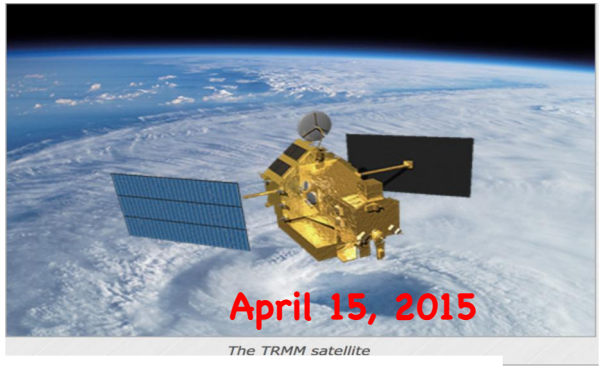
GFMS from TRMM to GPM

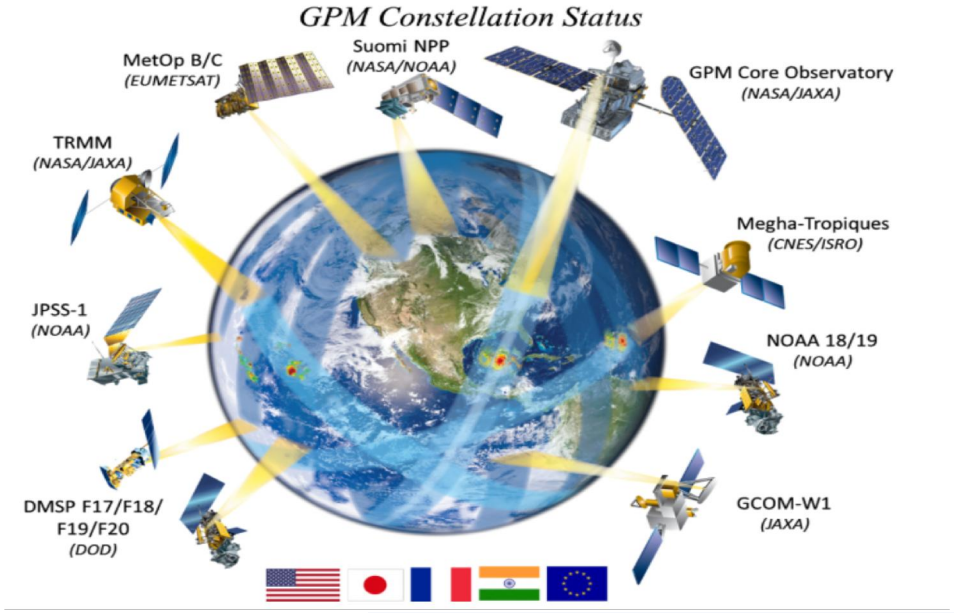
Search

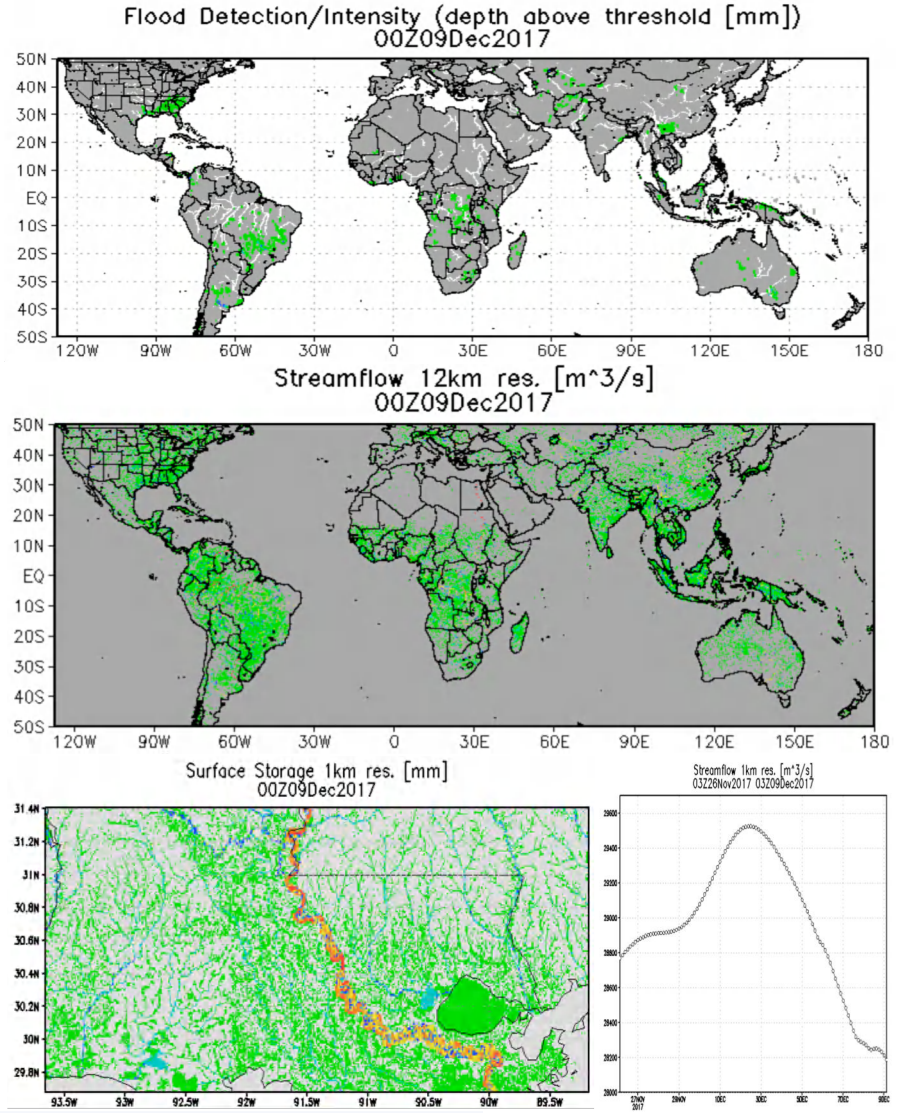
PRECIPITATION MEASUREMENT MISSIONS

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



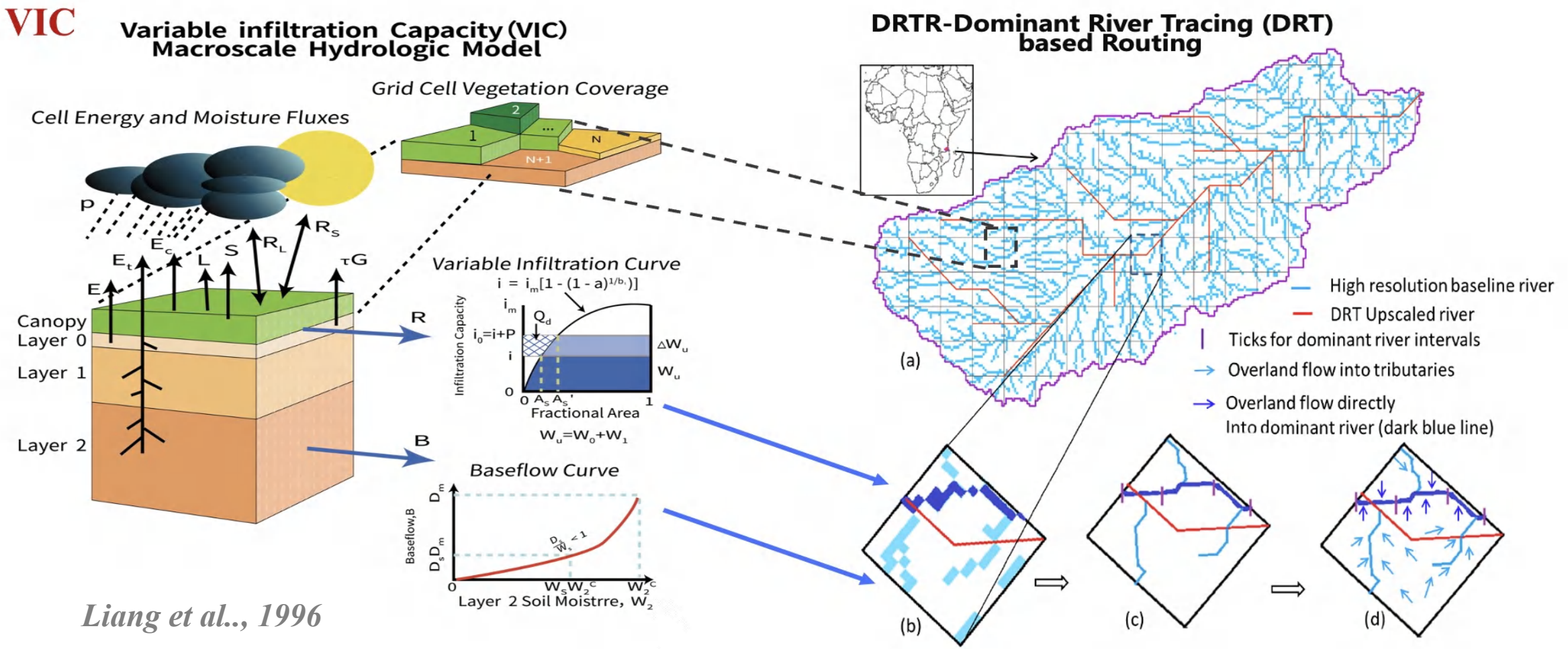






Global Flood Monitoring System (GFMS), since 2010

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



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

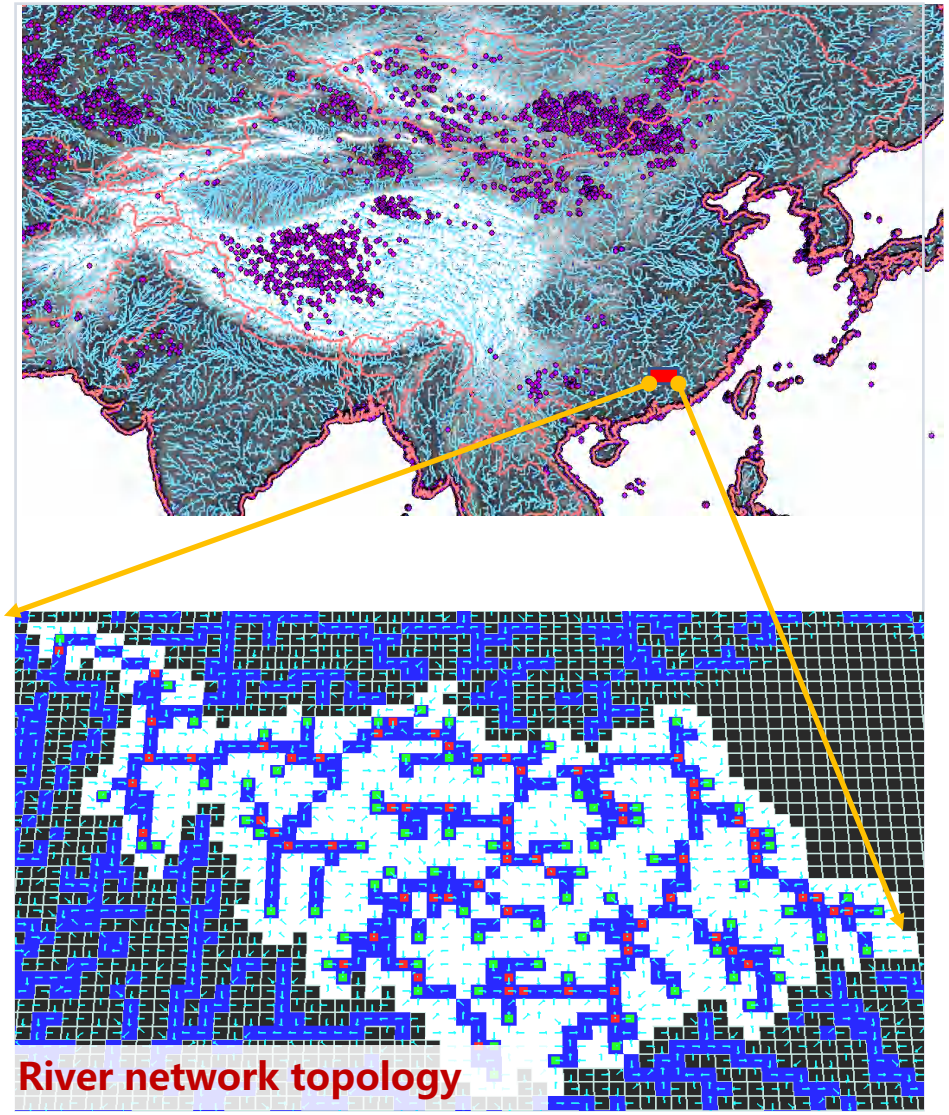
Flow direction, flow distance, slope, flow accumulation area, river width, river basin boundary etc.

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

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

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

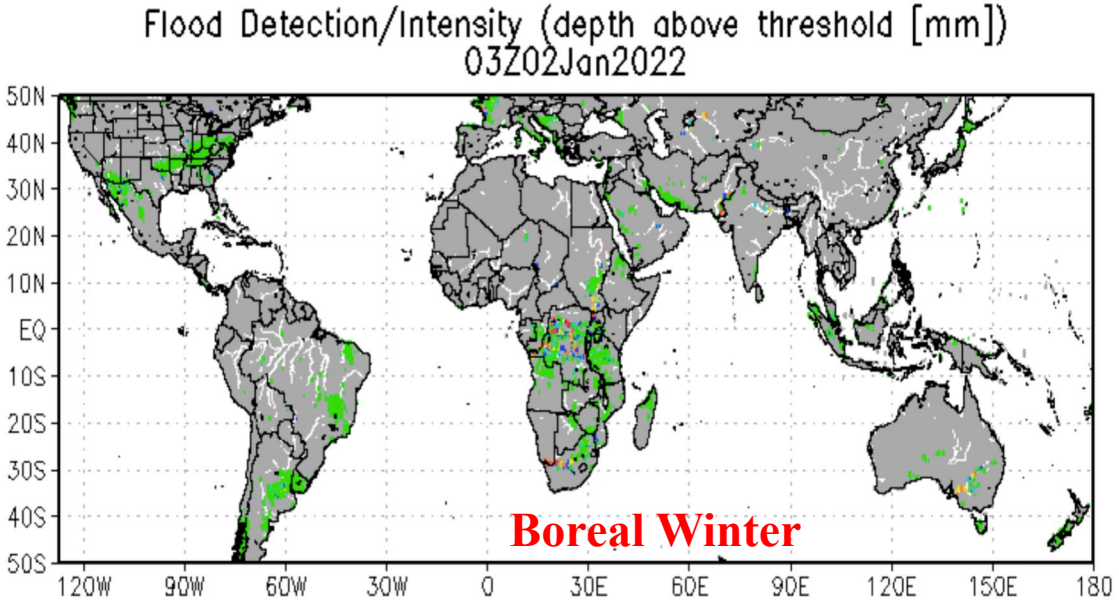
- **DRT derives drainage network with excellent performance in preserving the high resolution DEM information.**
- **DRIVE has strong stability and adaptability at various spatial resolutions.**

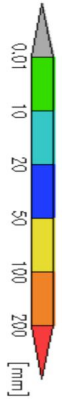


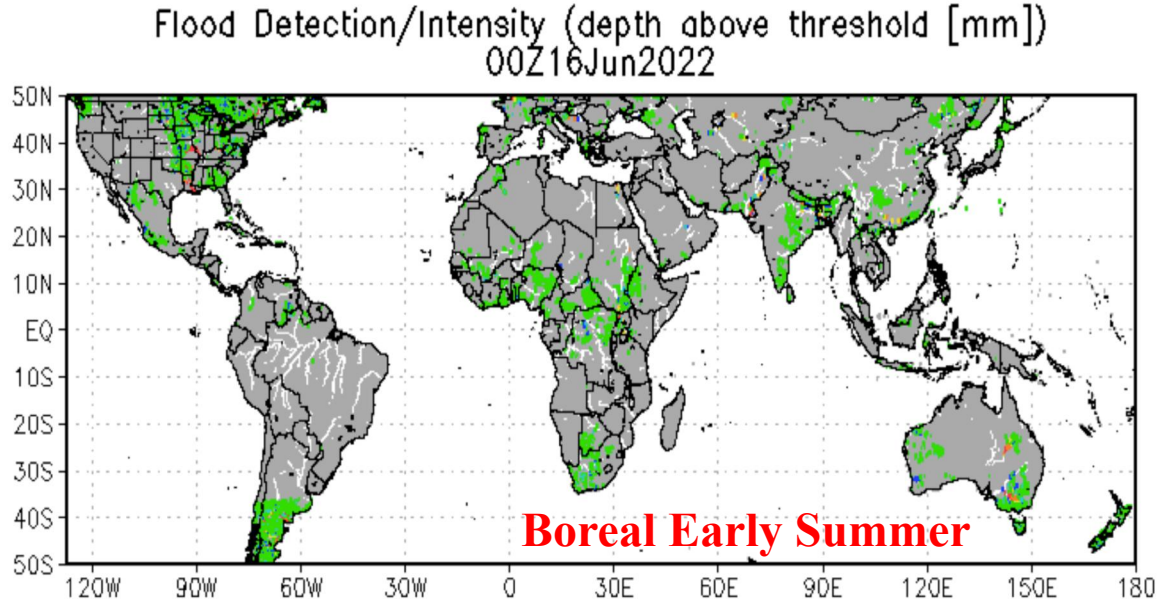
Wu et al., 2011, 2012, WRR

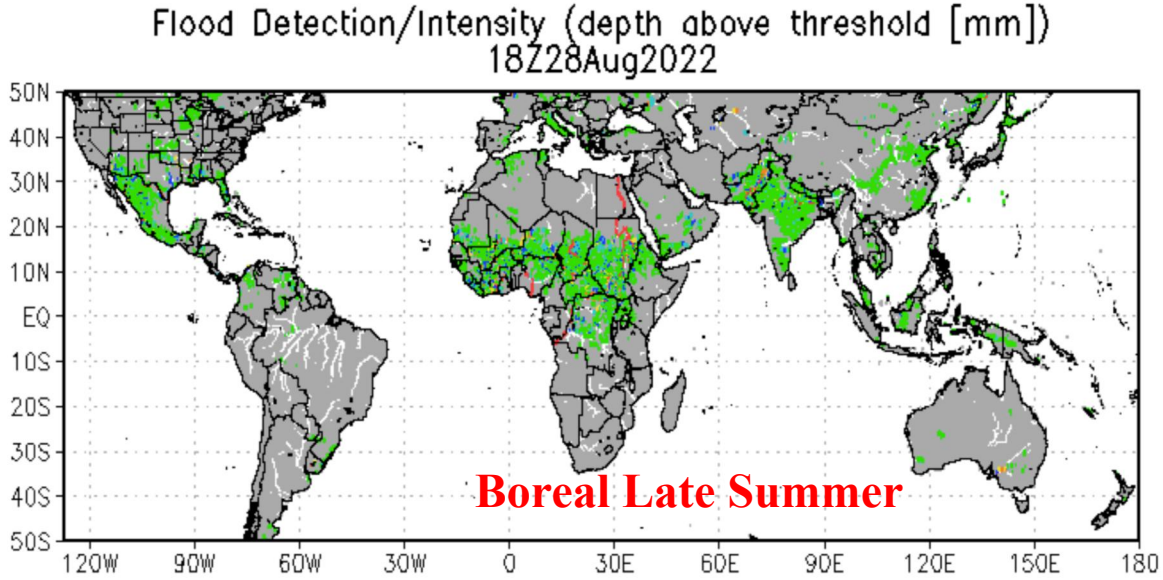
Global Flood Monitoring System (GFMS):

Flood happens almost everywhere in different format year to year





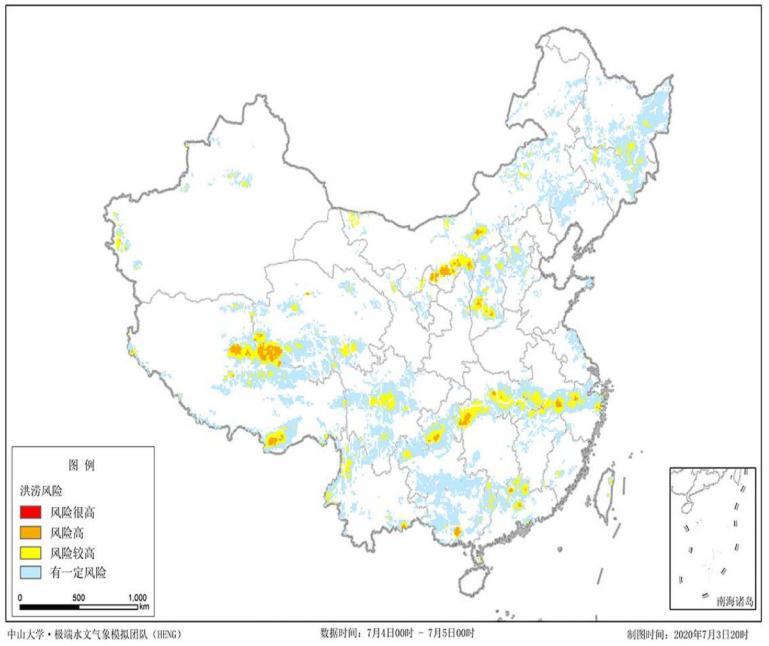




Floods at various spatial scales

Significant difference in the recent three flood seasons

2020

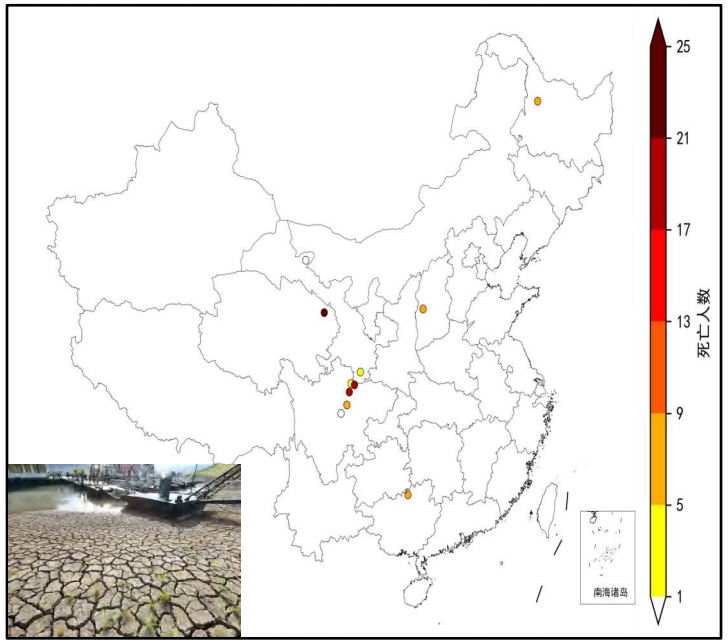


- Continental scale flooding
- From south to north
- From May to September

2021

- Mid-size river basin
- Extremely serious urban flooding in “Zhenzhou” in July

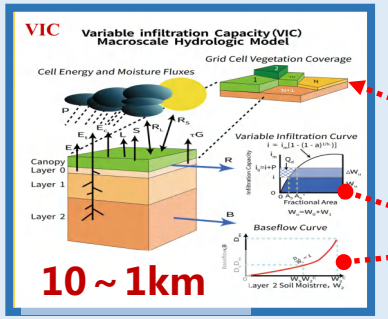
2022

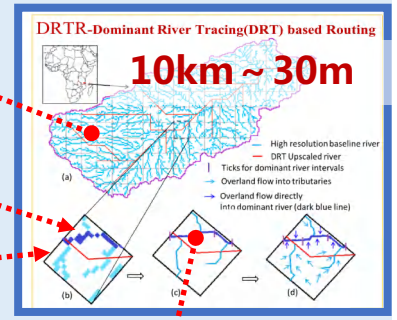


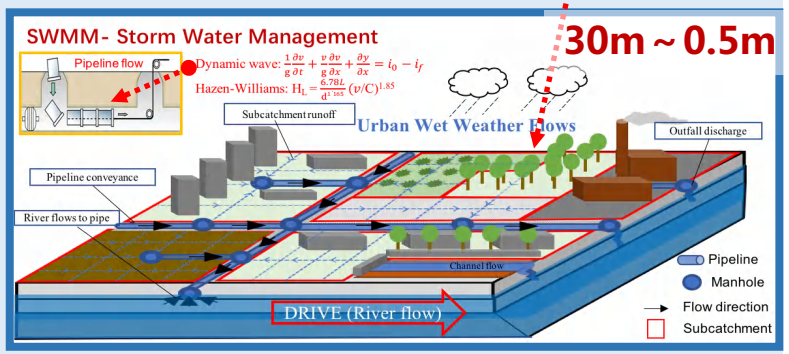
- Almost no river basin scale flooding
- Serious local (flash) flood
- More people loss (~100)

Glocal Hydrometeorological Solution on Floods (GHS-F)

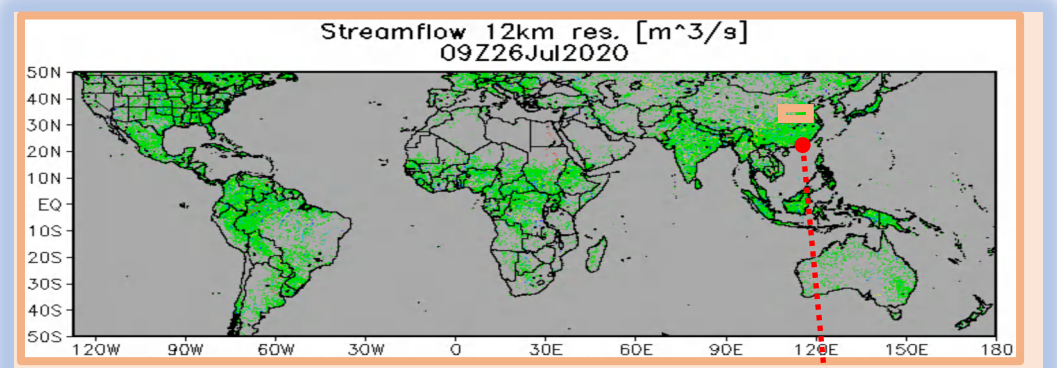
Modeling flash flood, river flood and urban flood from headwater to outlet.



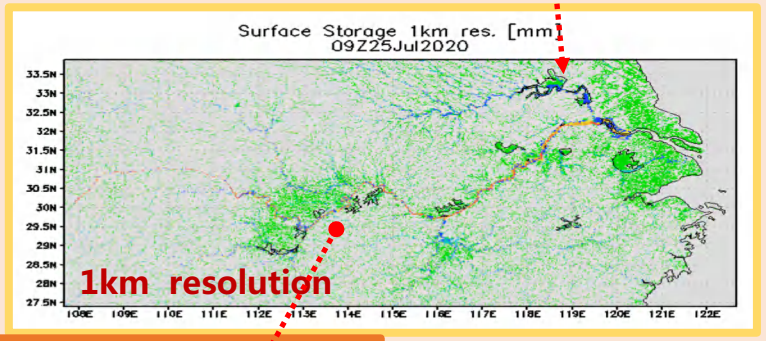


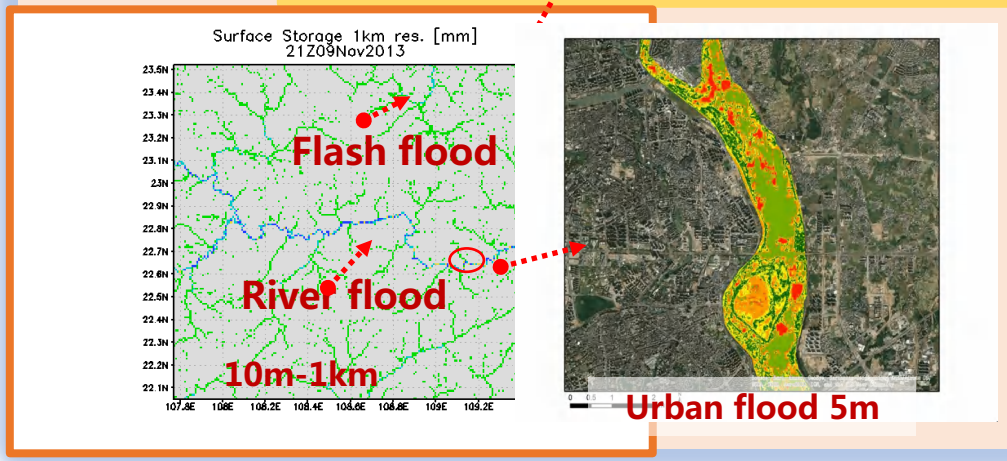


Hybrid-resolution coupled modeling of river-basin and urban hydrological and hydraulic processes.



Global to Local





- **Hourly update, at 10km-1km-5m resolutions, from global to local;**
- **Overall good performance in flood event detection with POD>90% with >20yr data records;**
- **Street level inundation POD can be >70%.**

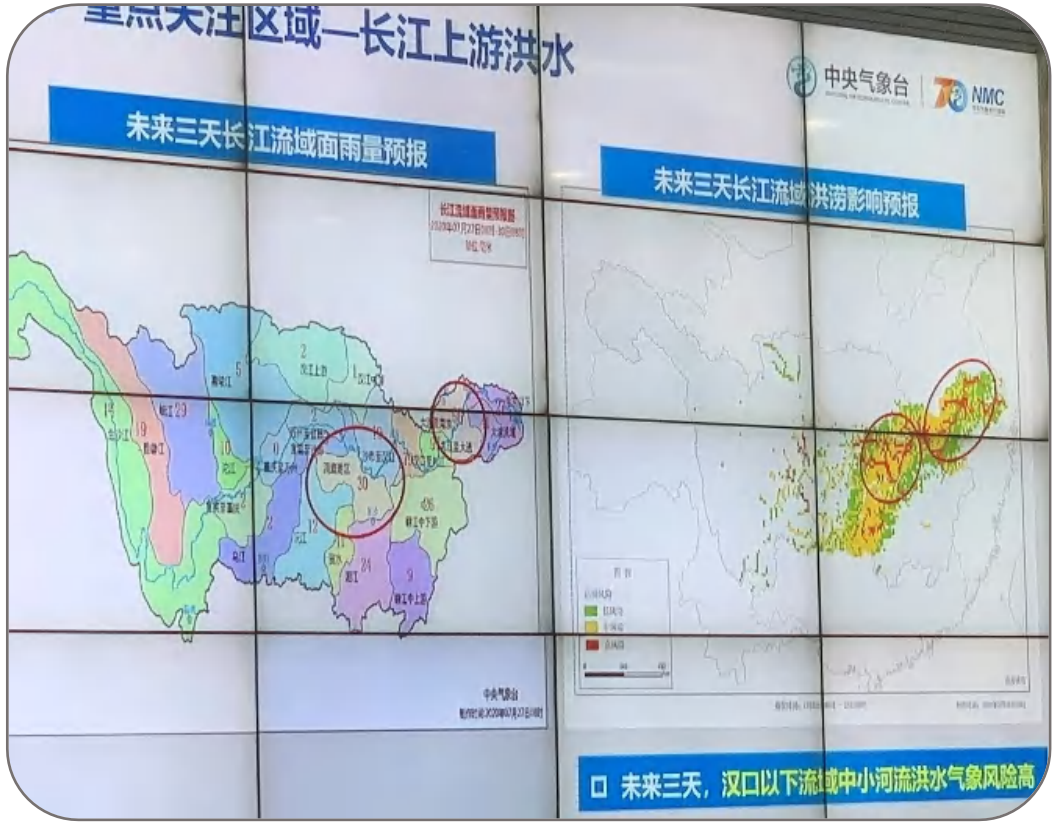
Wu et al., 2021, AAS

02

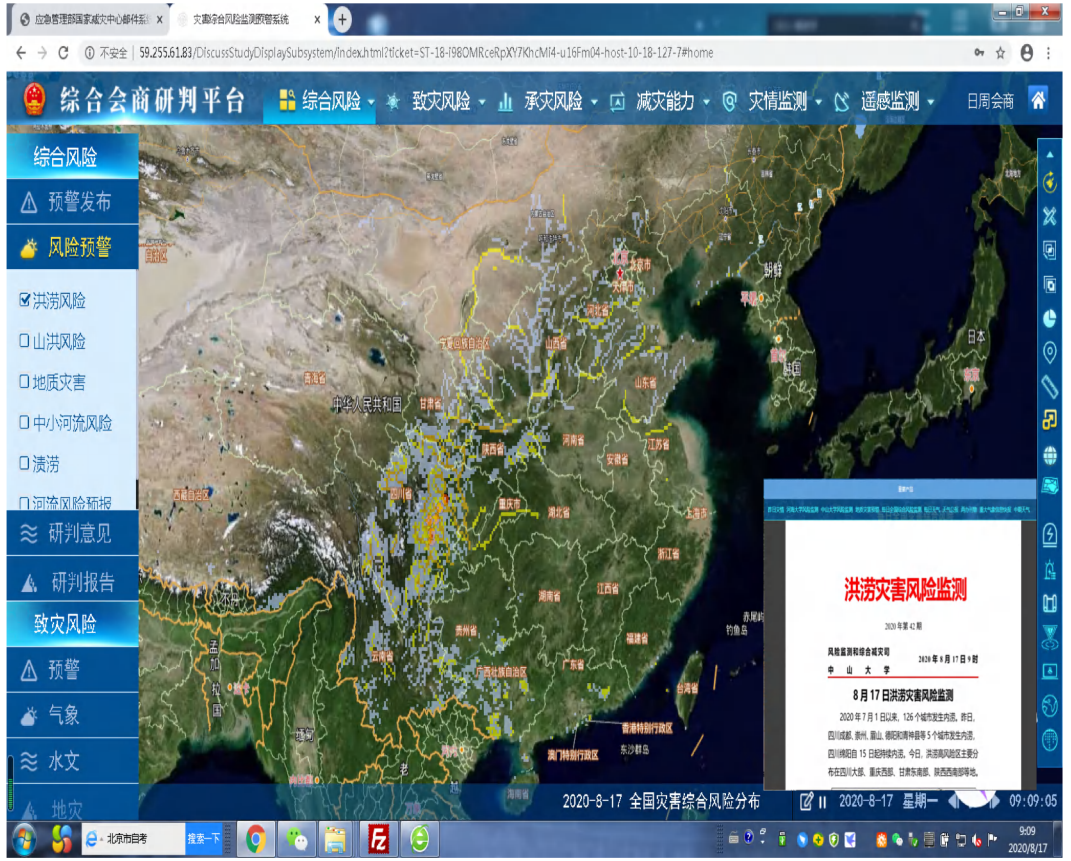
Practice in supporting operational agencies responsible to flood management and disaster mitigation

GHS-F operational applications

National Meteorological Center of CMA

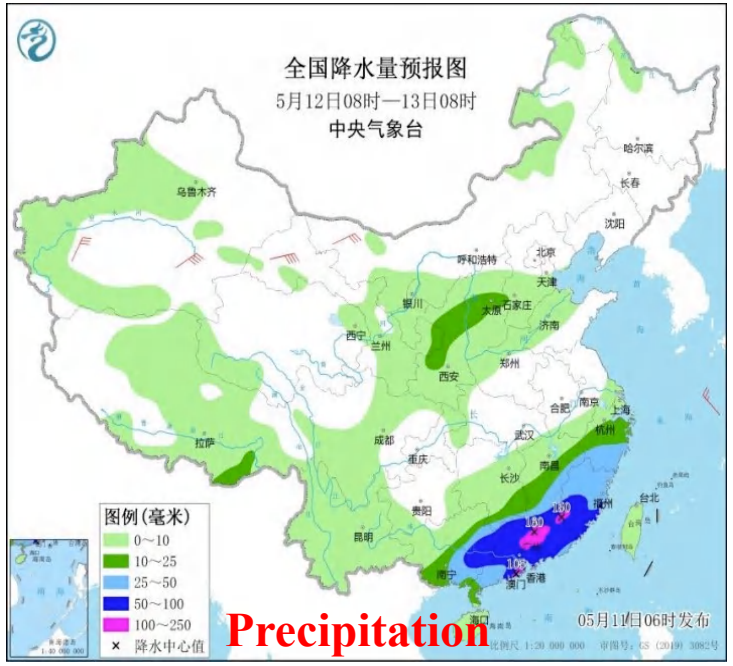


The Ministry of Emergency Management



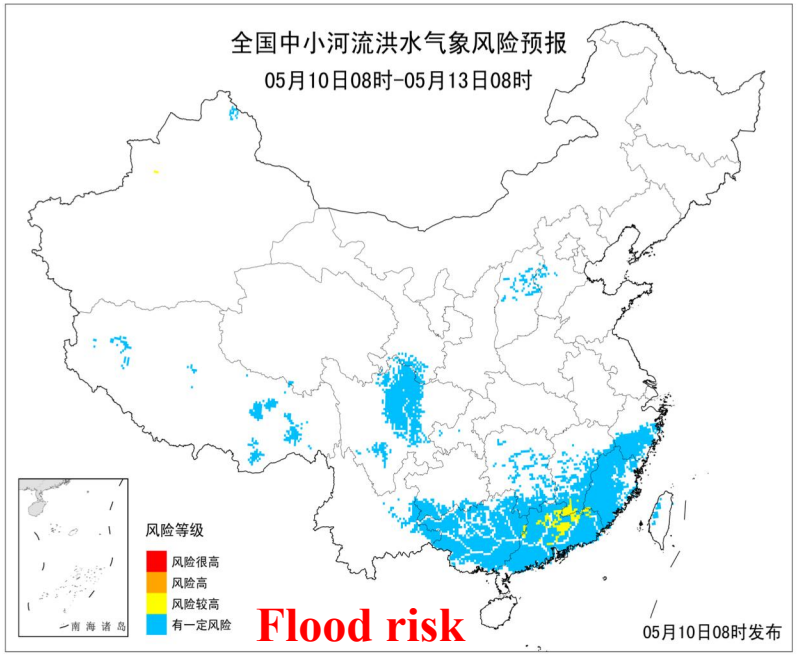
3-day flood forecast for China @CMA

3-hourly, 5km resolution flood risk forecast



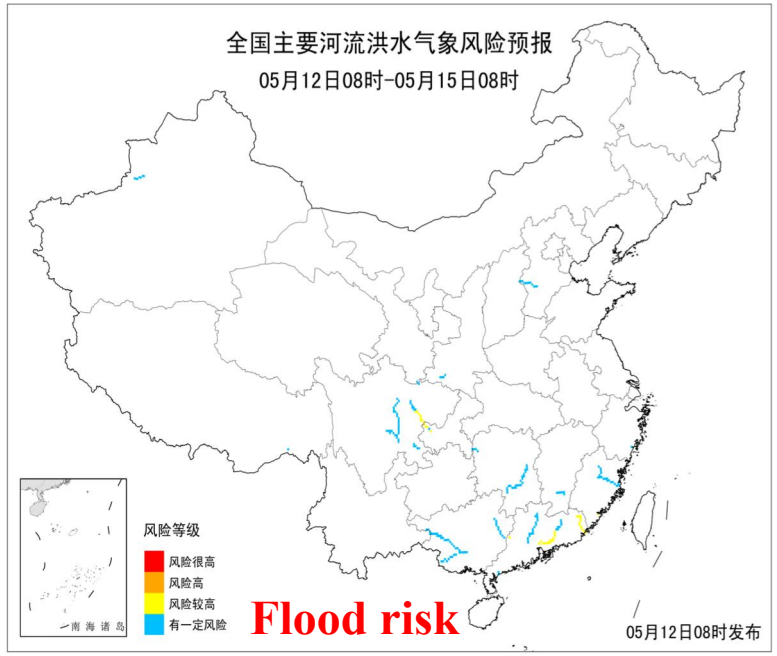
Precipitation

weather forecast



Flood risk

Small Rivers

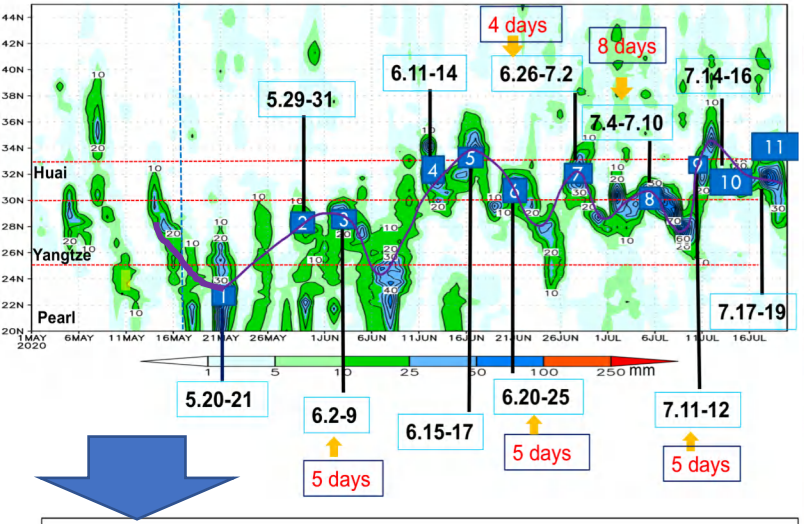


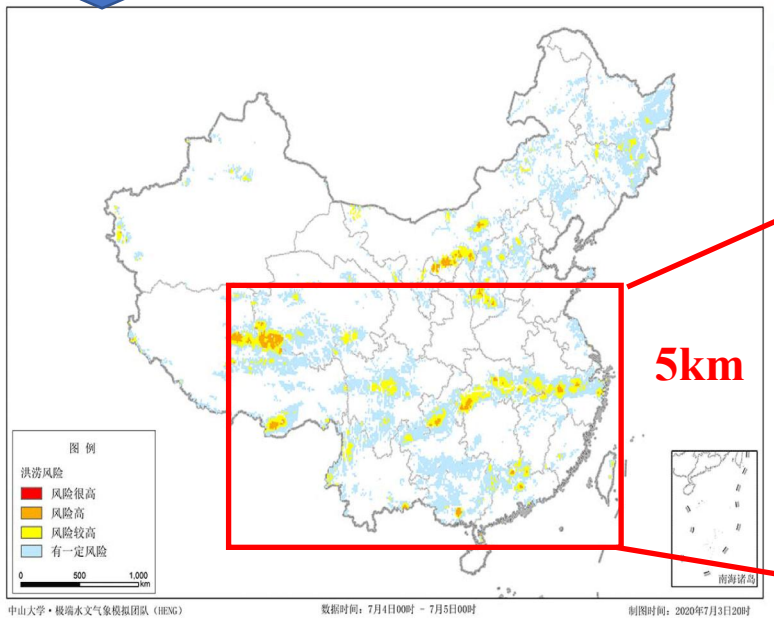
Flood risk

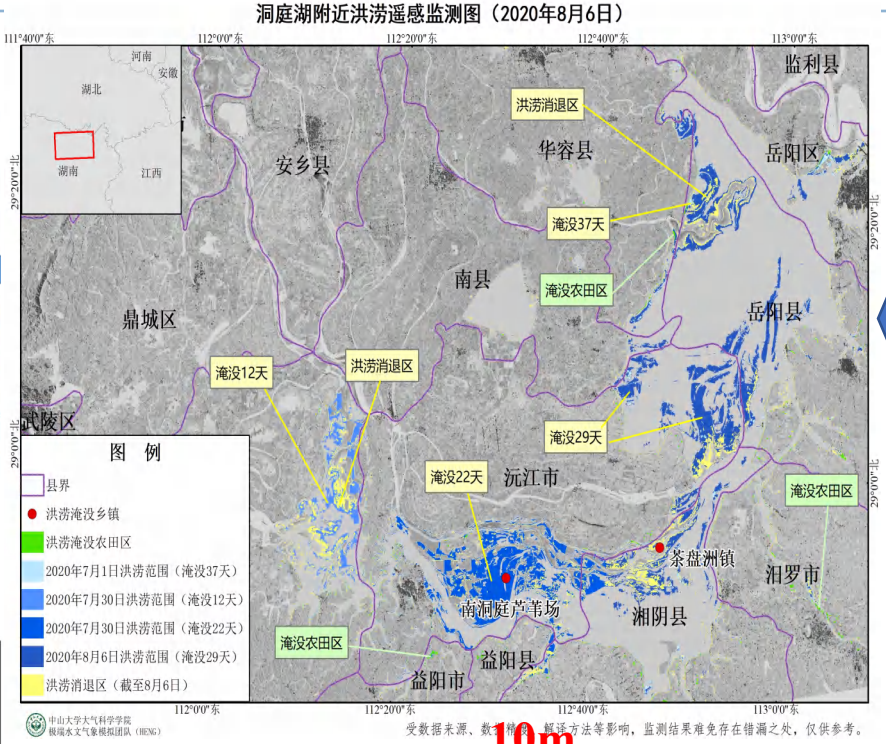
Large Rivers

Case 1: continental scale flooding, 2020

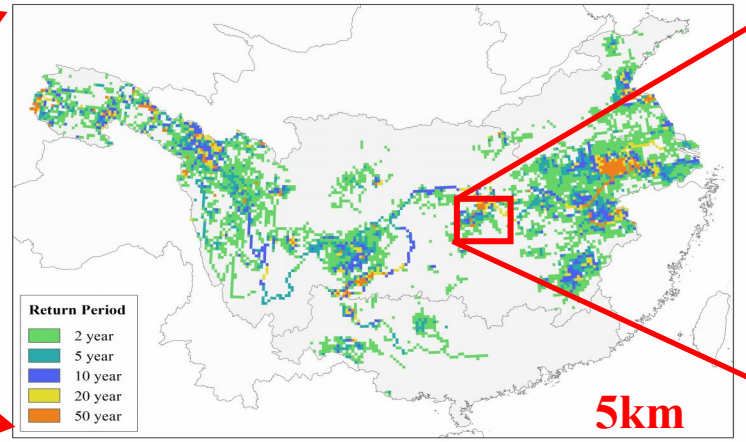
Daily zonal mean precipitation over part of mainland China (20°N-44.5°N)

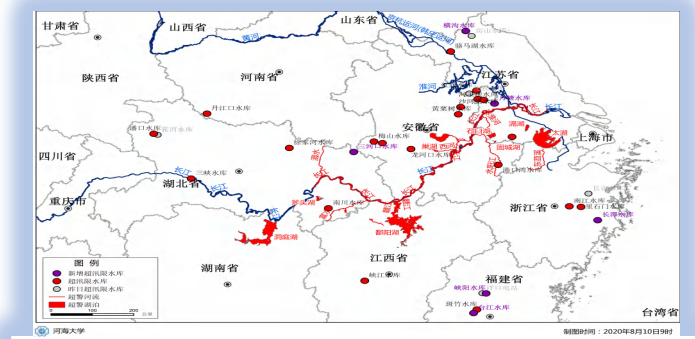


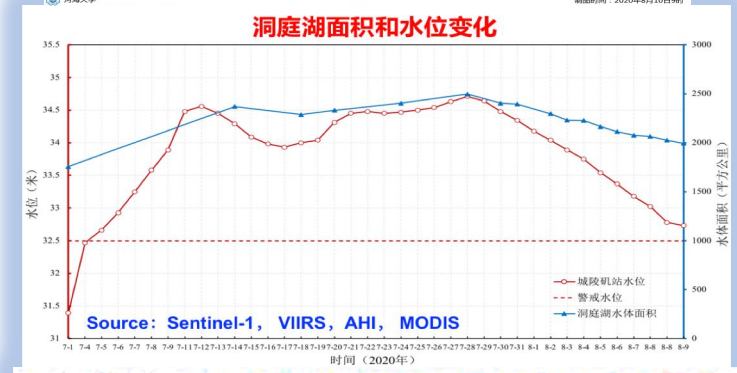


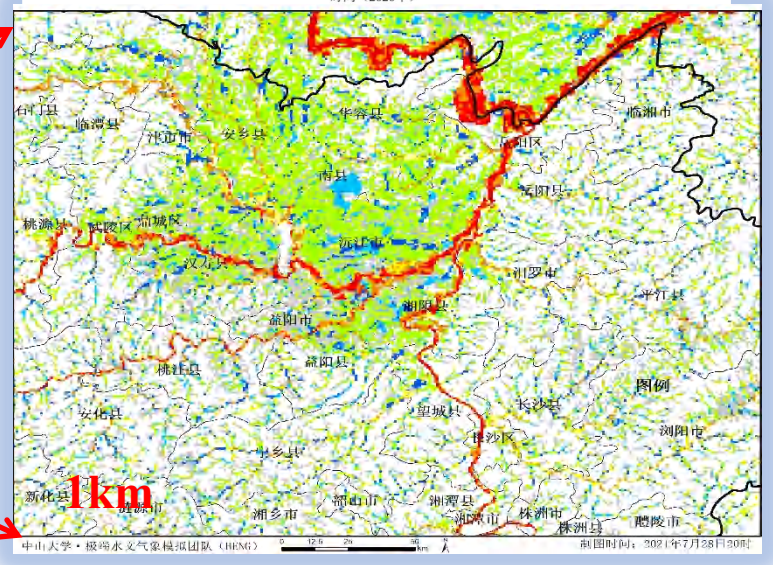


10m

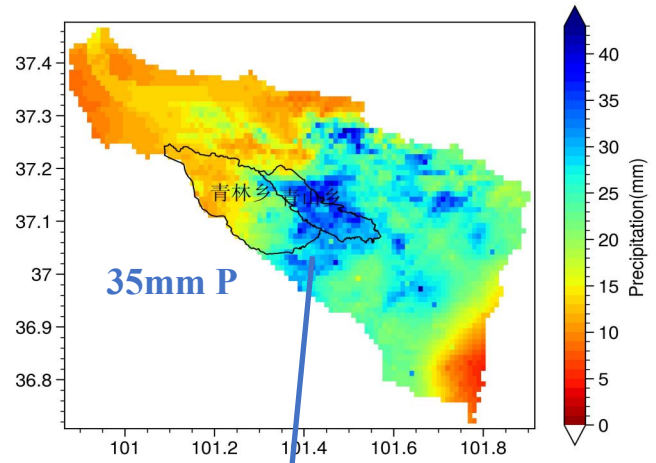


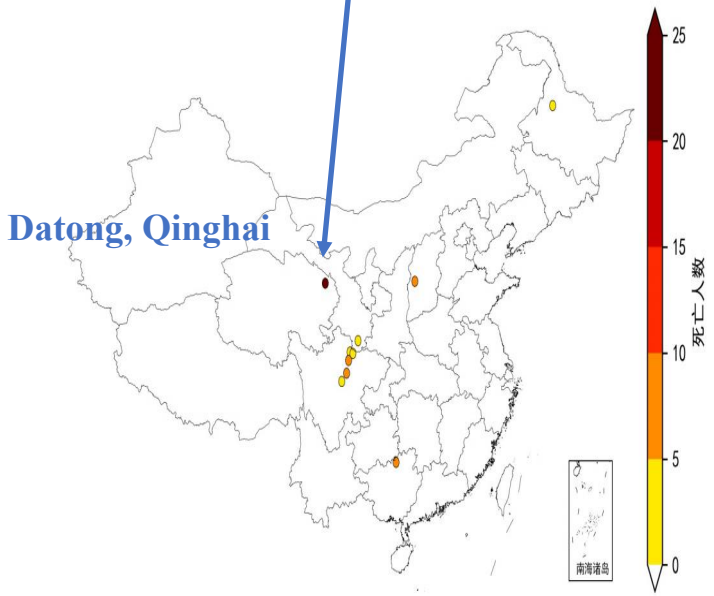




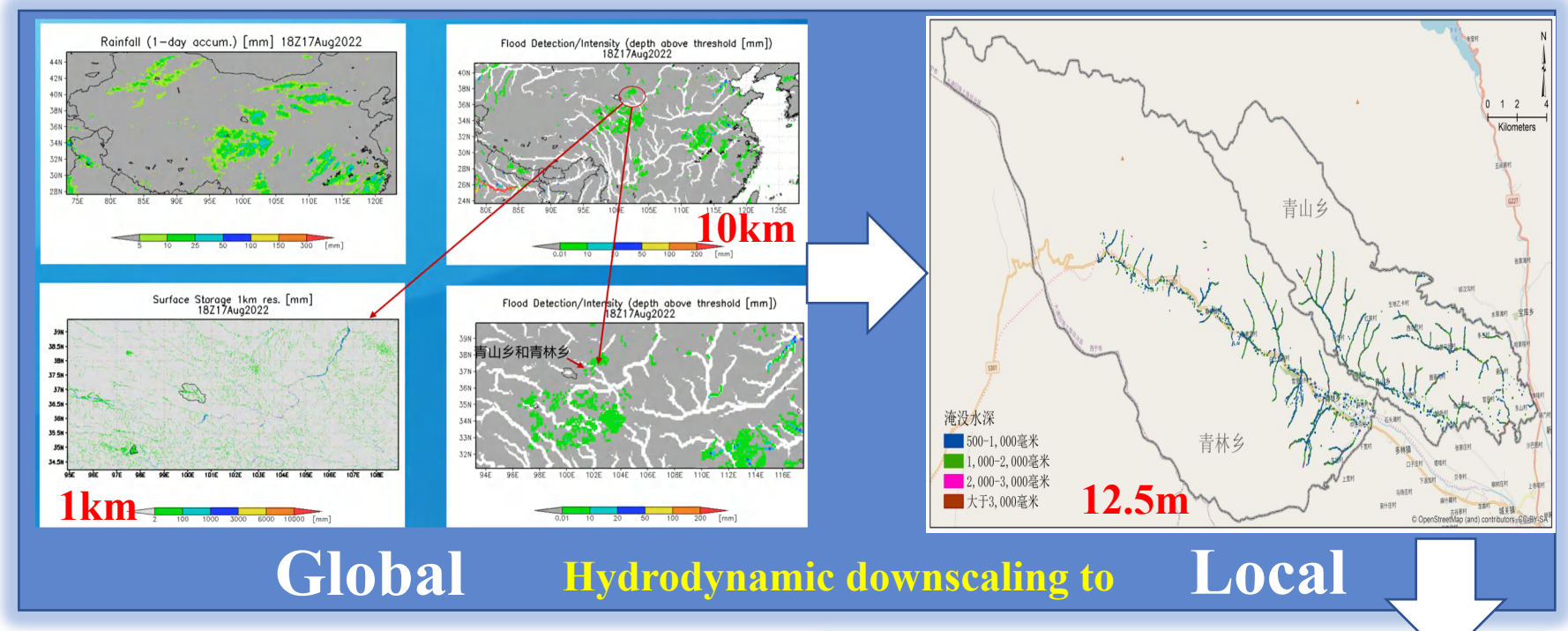


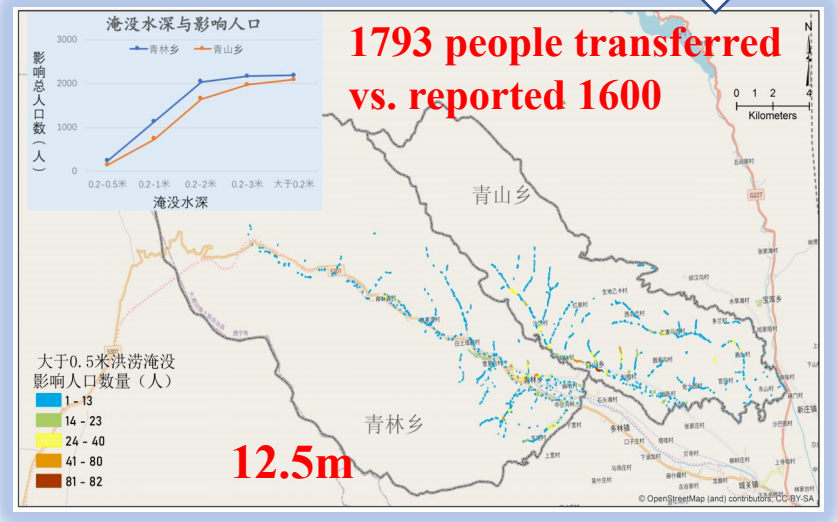
Case 2: Local scale (Flash) flooding, Aug. 18, 2022



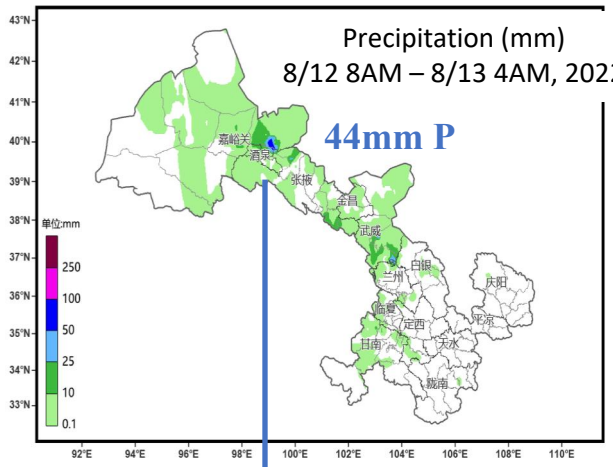


31 people loss

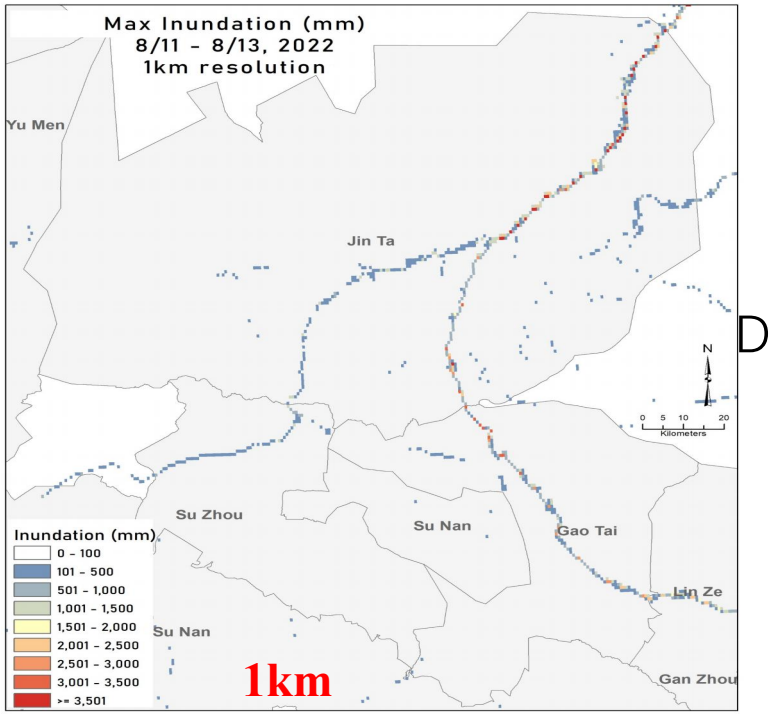




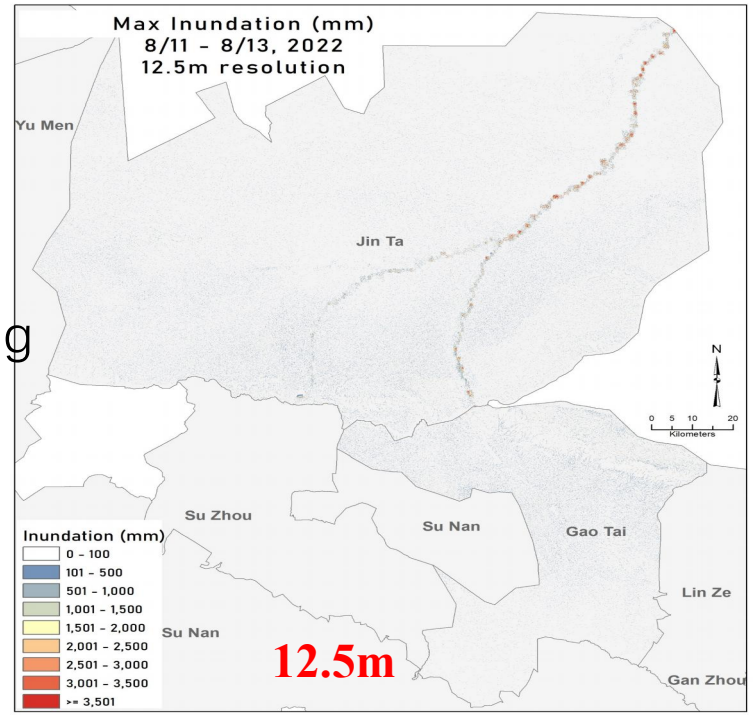
Case 3: Local scale (Flash) flooding, Jiuquan , Aug. 13, 2022



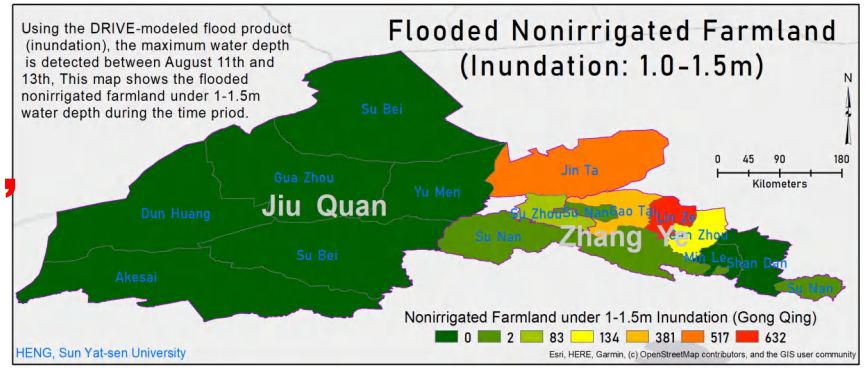
No people loss reported, but over 10k people transferred

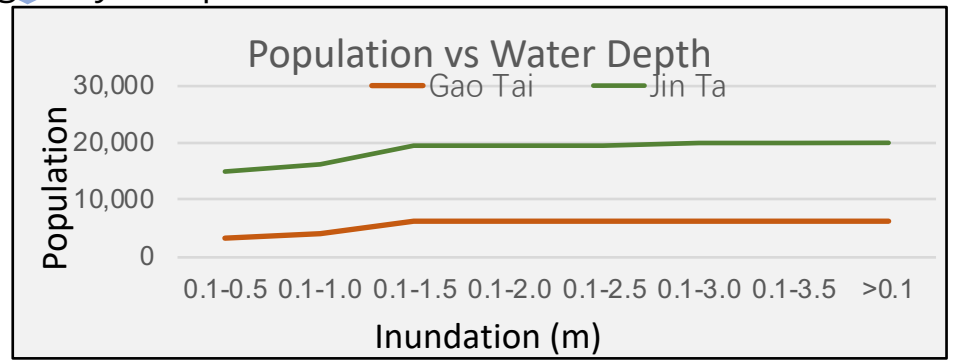


Downscaling



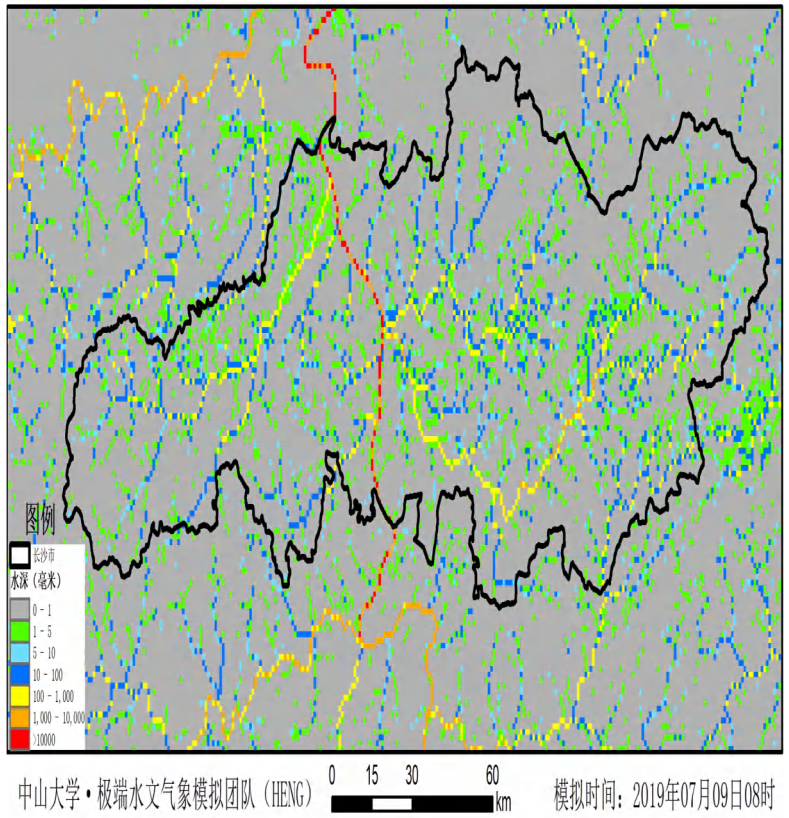
Flood Emergency Response



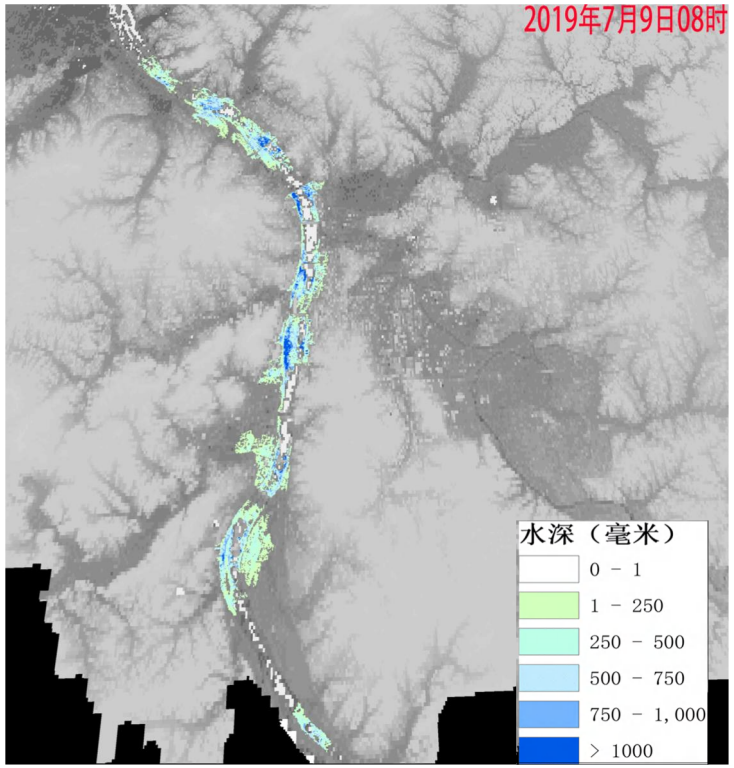


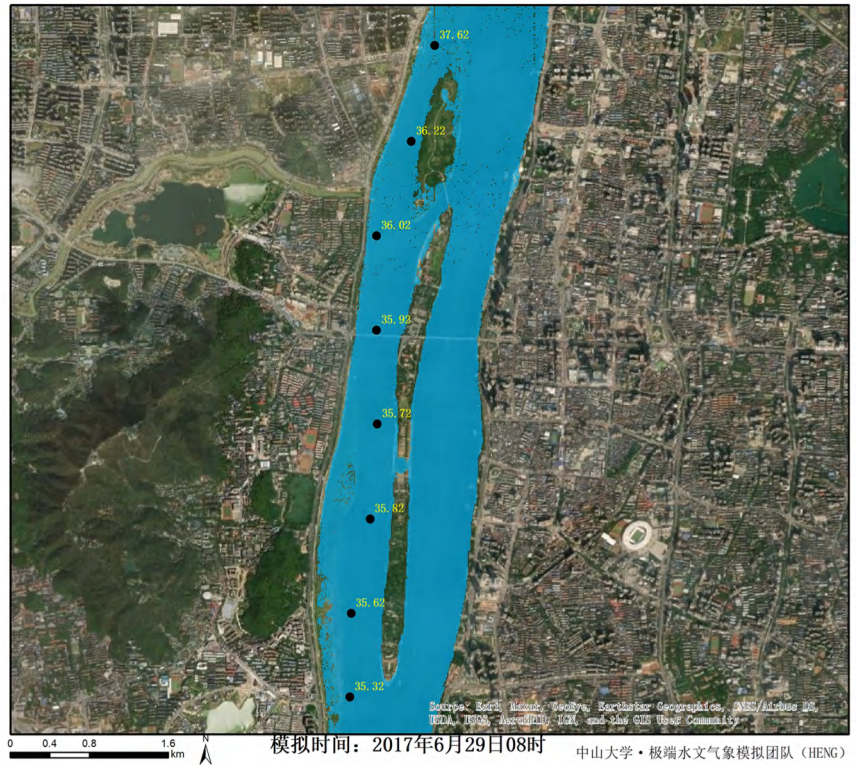
River-Urban flooding

River basin flooding meets Urban flooding



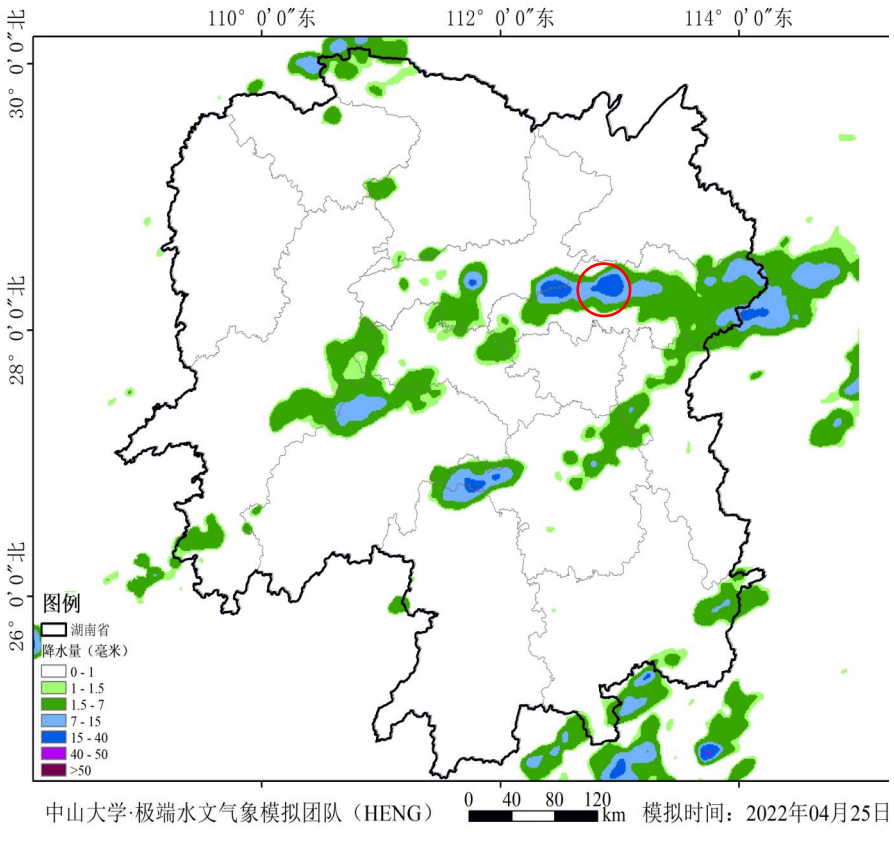
1km river flood modeling

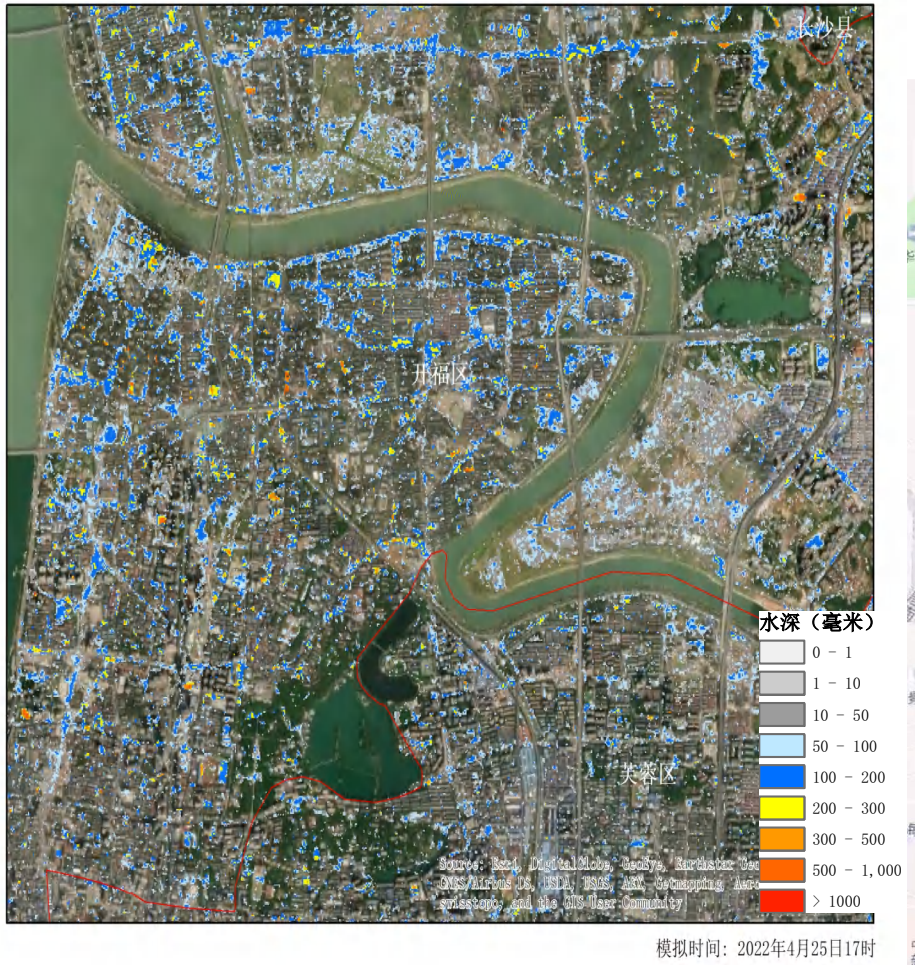




10m resolution coupled river basin-urban flood modeling

Case 4: Urban flooding in Changsha, Apr. 25, 2022





模拟时间：2022年4月25日17时

Cell photos are helpful

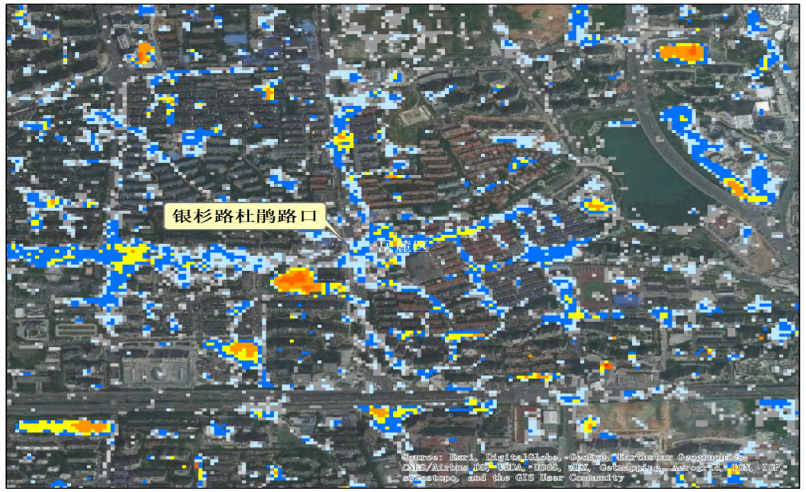
Case 4: Urban flooding in Changsha, Apr. 25, 2022

模拟时间：2022年4月25日16时

模拟时间：2022年4月25日17时

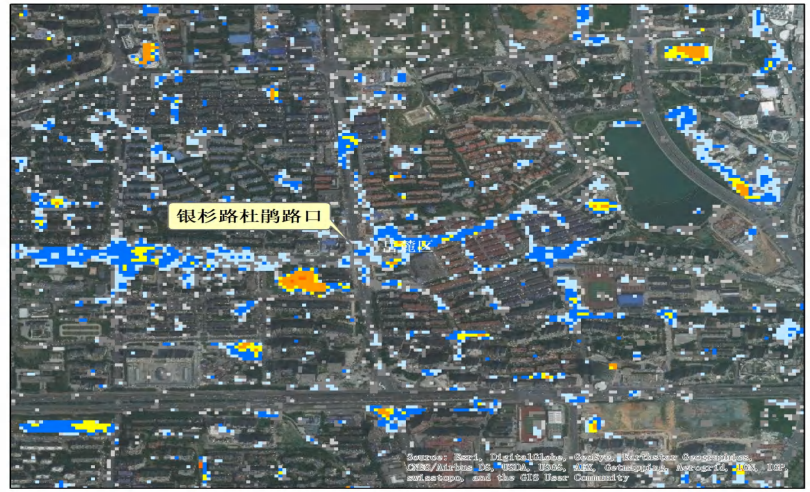
模拟时间：2022年4月25日18时

Street inundation were very well predicted according to ground information



模拟时间：2022年4月25日16时

模拟时间：2022年4月25日17时



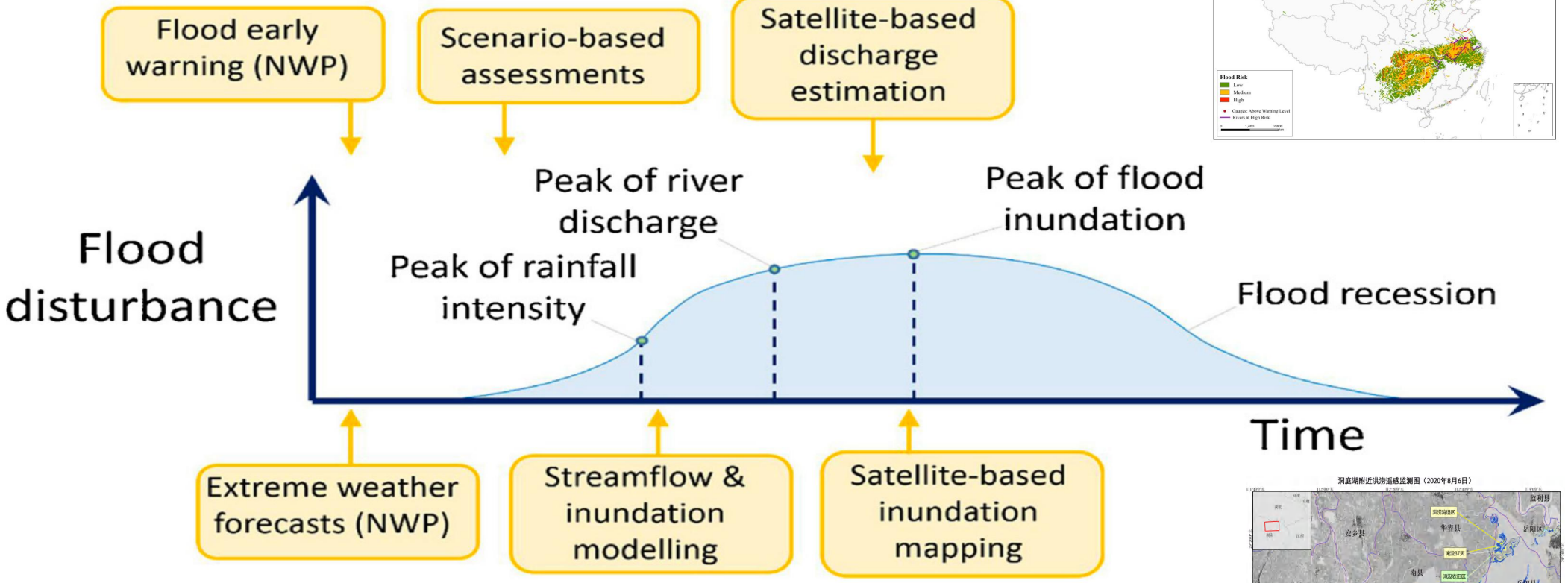
模拟时间：2022年4月25日18时

03

Two cents on developing trend

Global Flood Partnership: A global network for operational flood risk reduction

GFP
global flood partnership



Alfieri et al., *Environmental Science and Policy, 2018*

Rapid-response flood mapping during *Hurricane Harvey* by the *Global Flood Partnership (GFP)*

Sagy Cohen*, *University of Alabama (sagy.cohen@ua.edu)*; Robert Adler, *University of Maryland*; Lorenzo Alfieri, *EU Joint Research Centre*; G Robert Brakenridge, *University of Colorado*; Erin Coughlan, *VU University Amsterdam;* Zac Flamig, *University of Chicago*; John Galantowicz, *Atmospheric and Environmental Research;* Yang Hong, *University of Oklahoma;* Albert Kettner, *University of Colorado;* Patrick Matgen, *Luxembourg Institute of Science and Technology (LIST);* Son V Nghiem, *Jet Propulsion Laboratory, California Institute of Technolog;* Ana Prados, *University of Maryland;* Roberto Rudari, *CIMA Foundation;* Peter Salamon, *EU Joint Research Centre;* Mark Trigg, *University of Leeds;* Albrecht Weerts, *Deltares; Huan Wu, Sun Yat-sen University*

Hurricane Harvey made landfall as a Category 4 storm at the Texas Gulf Coast (near Rockport) on August 25, 2017, causing wind damage and storm surge-induced coastal flooding. The storm slowly moved east along the coast (meandering in and out of Gulf waters), in effect, stalling over southeast Texas and southwest Louisiana until September 1st. The slow-moving storm produced historically high amounts of rain over the region, with maximum accumulated rainfall of over 1,500 mm in southeast Texas. This led to catastrophic riverine and flash flooding in the region. Houston Metropolitan area (Texas) received over 750 mm of rainfall between August 24 and September 1, leading to widespread urban flooding, displacing scores of people and damaging properties and infrastructure. It was estimated that the Hurricane Harvey was the costliest natural disasters in US history, with a total estimated damage of over $180 billion.

GFP is not regularly activated for flooding events in first-world countries, as these typically have established flood prediction and observation capabilities. GFP activation for this event evolved as its magnitude became apparent. Below we provide a chronology of GFP activities during Hurricane Harvey:

Aug 25

Landfall

Source: National Weather Service; NASA Geostationary Operational Environmental Satellite; International Best Track Archive for Climate Stewardship (via nytimes.com)

Aug 27

GFP Partial Activation:
Dartmouth Flood Observatory (DFO) sent a limited-distribution email (not via GFP mailing list) informing about the activation of the 'International Charter', setting up of a DFO event webpage, and outlining available satellite imagery resources from before the flooding. The email led to inclusion of the recipients in the FEMA daily Remote Sensing Coordination and Geospatial Coordination calls which was later proved instrumental in connecting GFP products to the hurricane response community (including for the following flood events in Florida and Puerto Rico). The email was shared with NOAA National Water Center. A few hours following the initial email, precipitation and inundation predictions from GFMS were shared.

DFO Event webpage

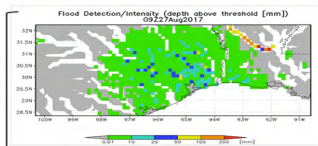
Dartmouth Flood Observatory | GFP | NASA

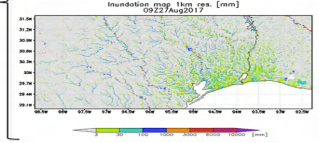
DFO Flood Event 4510

Hurricane Harvey, Texas and Lousiana

http://floodobservatory.colorado.edu/Events/2017USA4510/2017USA4510.html

GFMS Predictions



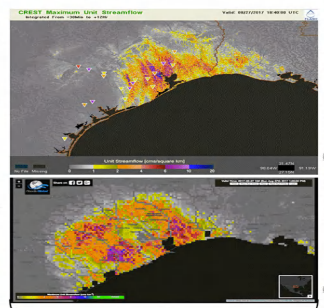


Acknowledgments for Son V Nghiem : "The research carried out at the Jet Propulsion Laboratory (JPL), California Institute of Technology, was supported by the NASA Land-Cover and Land-Use Change Program and by the NASA Terrestrial Hydrology Program." Sentinel-1 data contained modified Copernicus Sentinel data (2017), Thanks to D. T. Nguyen of JPL for SAR data processing to produce flood maps.

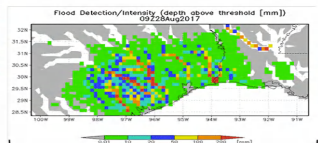
Aug 28

Flooding in Houston

GFP Full Activation:
The first email was sent to the GFP mailing list, proposing using this event as a case study to study GFP-members flood prediction systems. The same email also included streamflow predictions from the Flooded Locations And Simulated Hydrographs Project (FLASH). These predictions were re-distributed to a range of stakeholders (e.g. FEMA, NASA), an action which thereafter became standard operating procedure, with growing list of recipients.



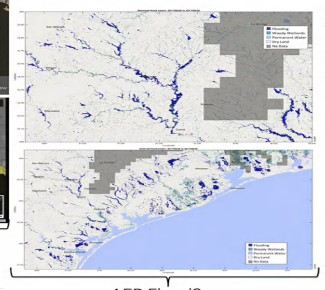
FLASH Products



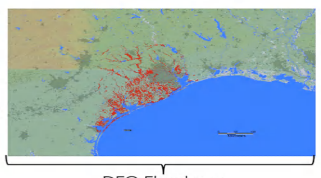
GFMS Predictions

Aug 29

Initial Remote Sensing Mapping:
DFO shared (via FEMA Geospatial Coordination email distribution) an update on flood mapping and modeling efforts, including using Radarsat images (from Aug 28) to map flooding, and sharing JPL-produced flood maps from the ALOS-2 satellite. The confidence in these products were relatively low. Atmospheric and Environmental Research (AER) shared (via GFP mailing list) a large-scale 90-m resolution flood map of the impacted area, analyzed from the AMSR2 (passive microwave) sensor using an experimental configuration of the FloodScan system. Link between DFO/GFP to the State Operations Center of the Texas Division of Emergency Management (TDEM) was established which initiated data sharing via the TDEM data server (restricted access).



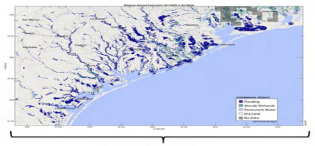
AER FloodScan



DFO Flood map

Aug 30

SAR-based Mapping:
Following a pass by Sentinel-1 satellite, SAR-based flood maps were shared by Luxembourg Institute of Science and Technology (LIST), JPL and DFO. DFO ftp server was used to store and distribute the GIS files of these, and future, products relating to this event. AER produced an updated maximum flood map for the region using new AMSR2 imagery, which was shared via the GFP mailing list. It was then distributed to the FEMA Geospatial Coordination mailing list (now over 300 recipients) and was uploaded to the TDEM data server.

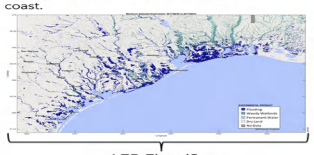


AER FloodScan

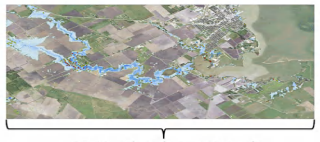
LIST

Aug 31

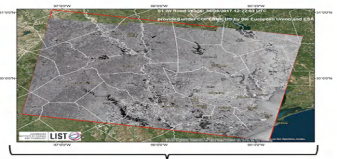
Additional Sentinel-1 imagery was shared by LIST via the GFP mailing list. DFO provided an updated inventory of GFP-produced flood maps and links to its event-dedicated web-portal and ftp server. The Surface Dynamics Modeling Lab (SDML) shared a floodwater depth map based on the AER maximum flood extent map and a DEM. AER shared updated large-scale maximum flood extent maps incorporating AMSR2 data from August 30 and set up a FloodScan web interface with daily Hurricane Harvey maps. LIST shared SAR-based flood map covering the Houston area from a 30 August Sentinel-1 pass. Aerial photography was becoming available via NOAA but with limited coverage outside the coast.



AER FloodScan



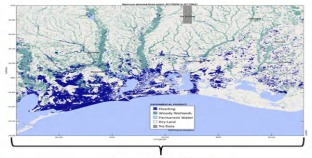
SDML Floodwater Depth



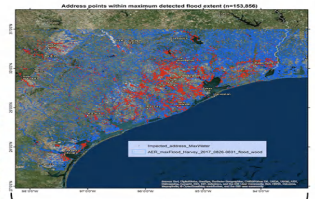
LIST

Sep 1

AER shared updates from AMSR2 passes on 31 August, revealing the extent of flooding in east Texas (Beaumont area). SDML shared a building impact map based on AER maximum flood extent map and address points layer from the TDEM server (uploaded by University of Texas, Austin).



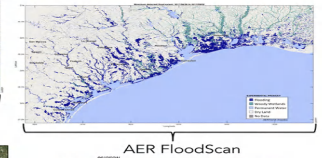
AER FloodScan



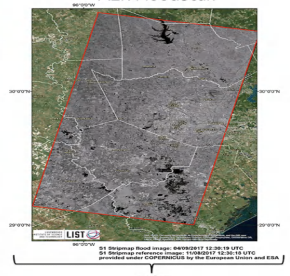
SDML Floodwater Depth and building impact

Sep 2 onward

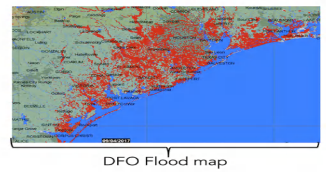
AER shared final maximum flood extent estimates incorporating all AMSR2 data 26 August - 2 September with expanded coverage into Louisiana. LIST shared flood maps from two Sentinel-1 passes on 4 September. DFO shared a maximum extent map based on Sentinel-1 imagery. DFO website was updated to include these and other final products:
http://floodobservatory.colorado.edu/Events/2017USA4510/2017USA4510.html



AER FloodScan



LIST



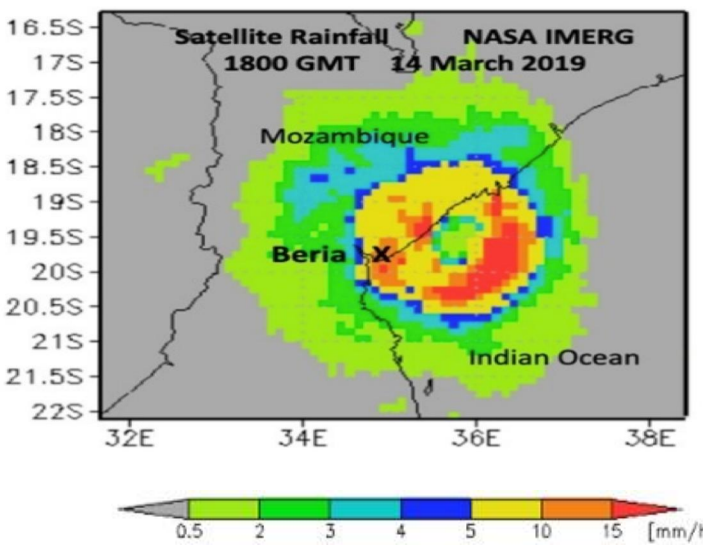
DFO Flood map

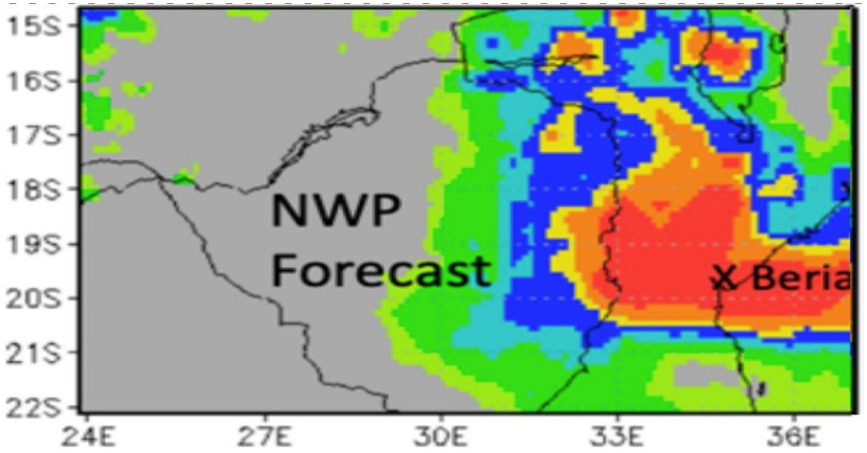
GFP global flood partnership

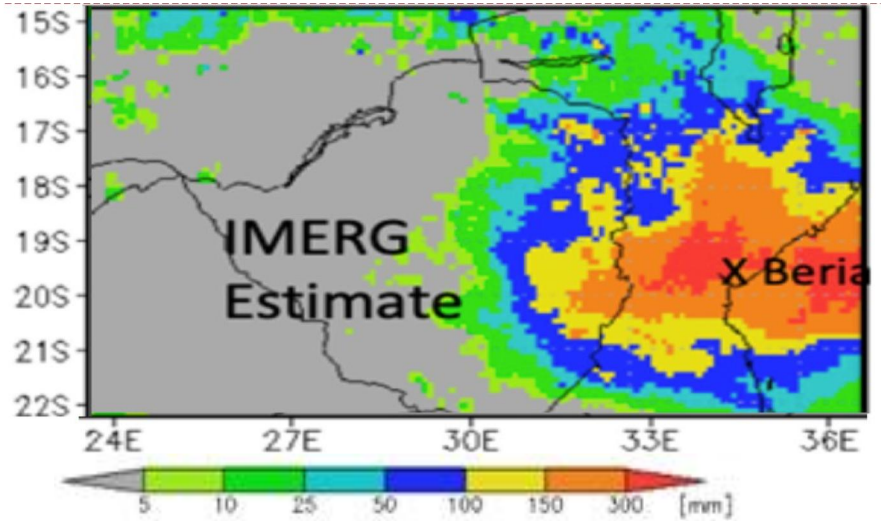
https://gfp.jrc.ec.europa.eu

Mozambique, Cyclone Idai,14-19 March 2019

NWP forecast peak totals were ~ 1000 mm, while peak satellite estimates (IMERG) were ~ 600 mm. Ground validation was missing/questionable.



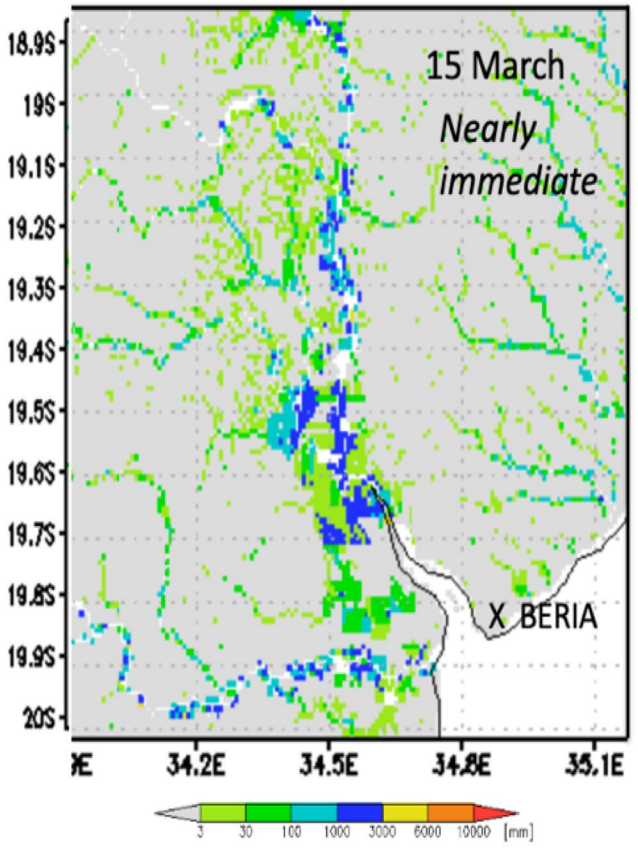




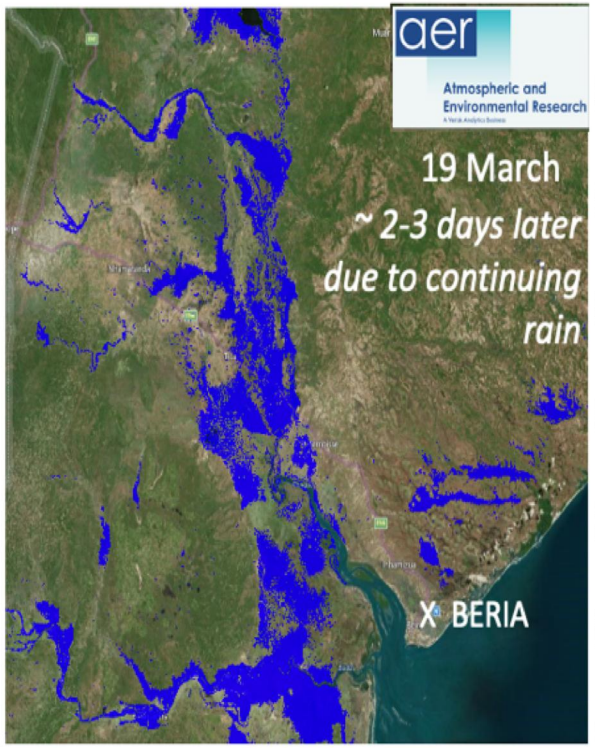
3-Day Forecast Rain from 14 March (from NASA GEOS NWP model)

Adler and Wu et al., 2020, JFRM

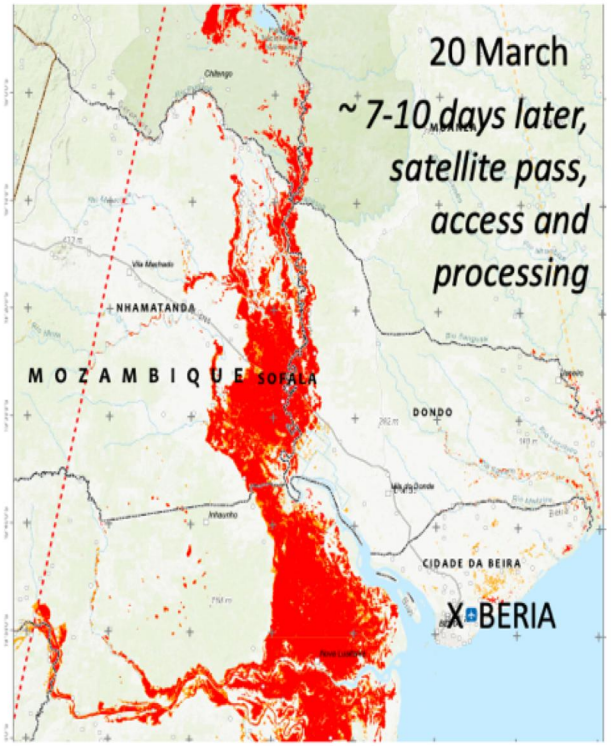
GFMS: based on Satellite Rain into Land Surface and Routing Models



FloodScan from AER: based on Passive Microwave (37 GHz) and DEM



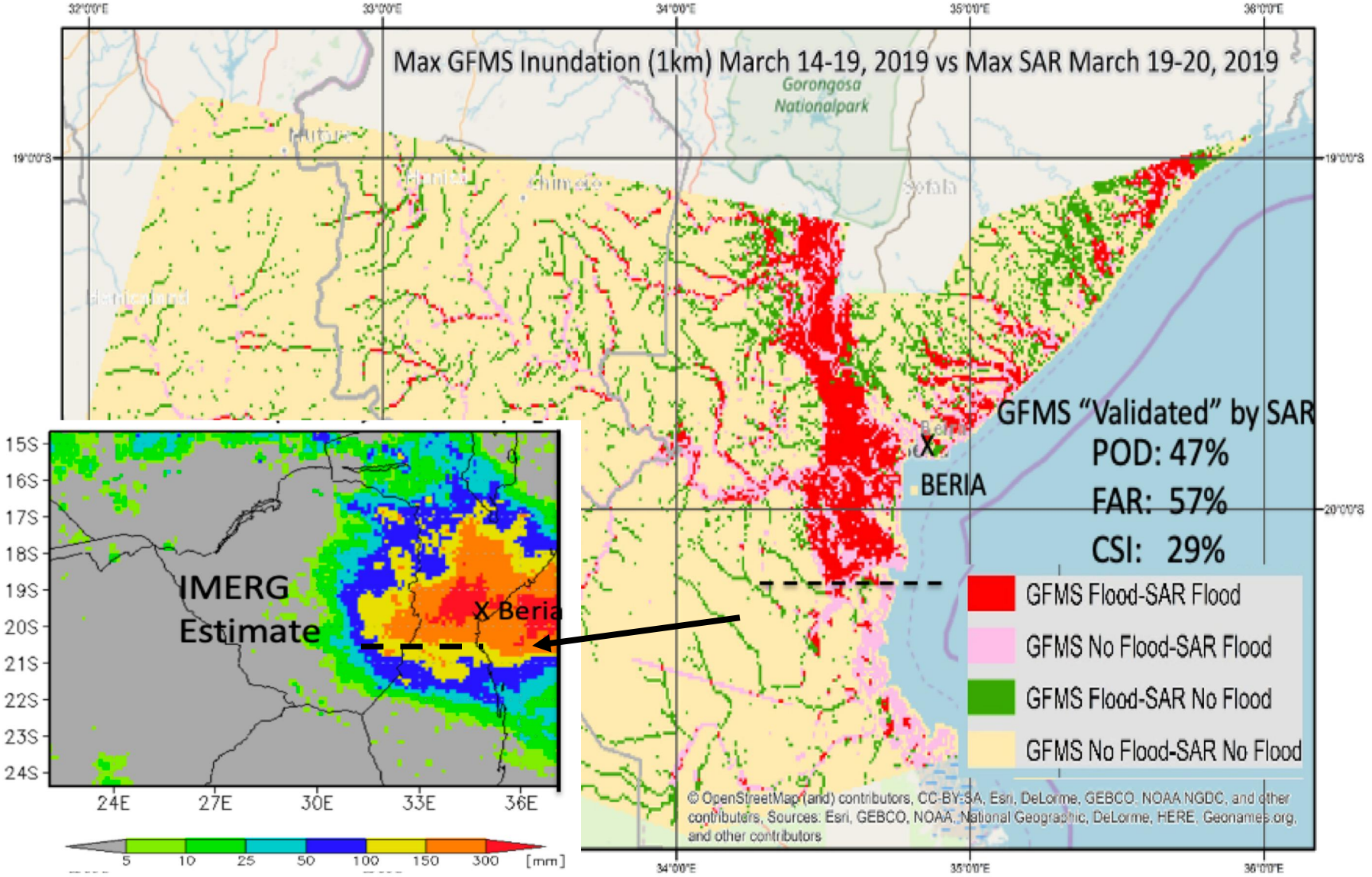
SAR: Sentinel 1 (Analysis by UNOSAT)



March 15 → March 19 → March 20

Time Integrated Inundation from GFMS compared to SAR

Maximum Inundation from GFMS (14-19 March) vs. Max Inundation from SAR (LIST)

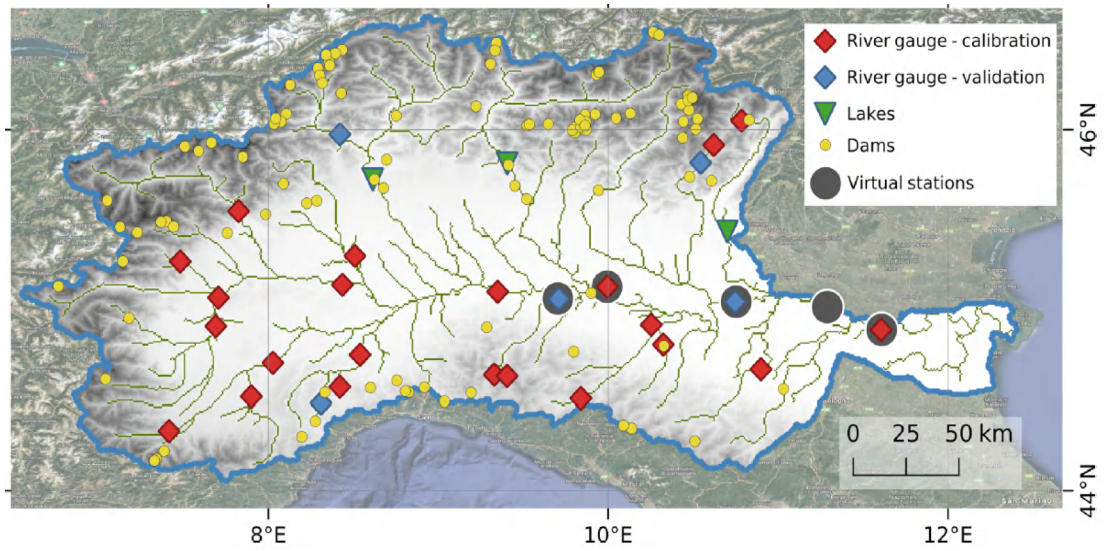


Adler and Wu et al., 2020, JFRM

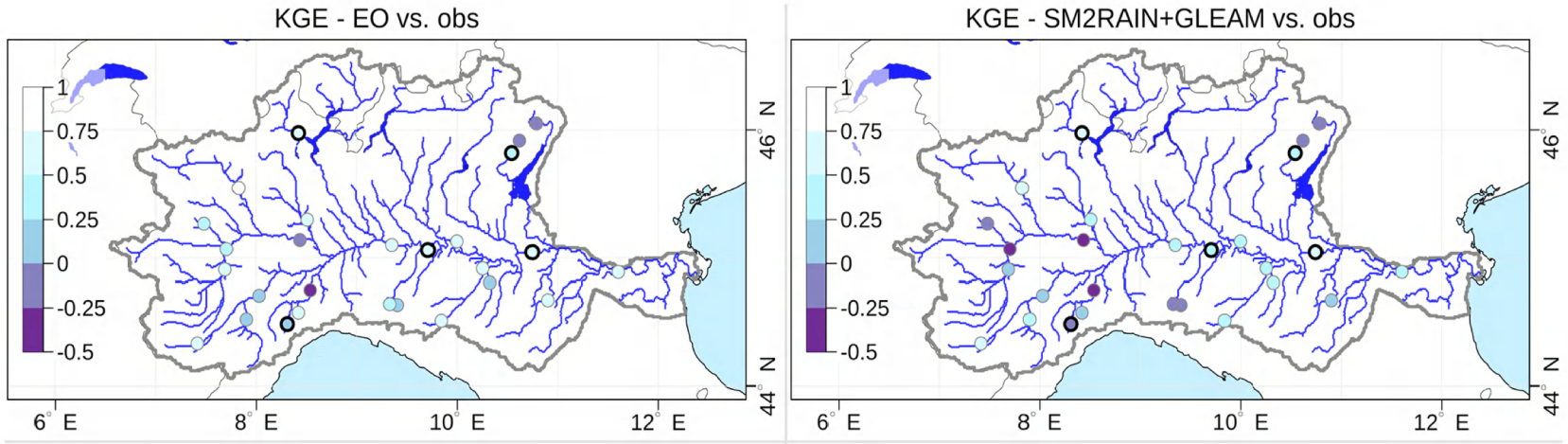
High-resolution satellite products improve hydrological modeling in northern Italy

Hydrology and Earth System Sciences
Open Access
EGU

Lorenzo Alfieri[1], Francesco Avanzi[1], Fabio Delogu[1], Simone Gabellani[1], Giulia Bruno[1], Lorenzo Campo[1], Andrea Libertino[1], Christian Massari[2], Angelica Tarpanelli[2], Dominik Rains[3], Diego G. Miralles[3], Raphael Quast[4], Mariette Vreugdenhil[4], Huan Wu[5,6], and Luca Brocca[2]



- Hydrological model **fully driven by satellite** (i.e., P and ET while assimilating satellite derived soil moisture (SM) and snow depths);
- **Model calibration** uses satellite-based precipitation, evaporation, and river discharge;
- Satellite-driven operational hydrological applications show skillful estimates of river discharge.



Po River basin (Italy)

Alfieri et al., 2022, HESS

Different lead-time flood forecast

GFP global flood partnership

A global network for operational flood risk reduction

气候变化 季节/次季节 延伸期 中期 短期 监测

Statistical model

Dynamical model

100y 90d 30d 10 days 0-3 days

Flood disturbance

Time

Flood early warning (NWP)

Scenario-based assessments

Satellite-based discharge estimation

Peak of river discharge

Peak of flood inundation

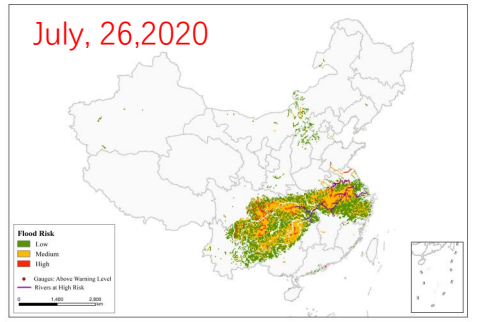
Peak of rainfall intensity

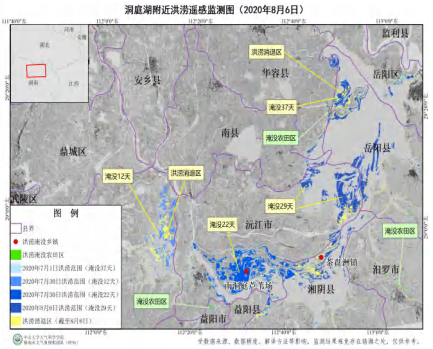
Flood recession

Extreme weather forecasts (NWP)

Streamflow & inundation modelling

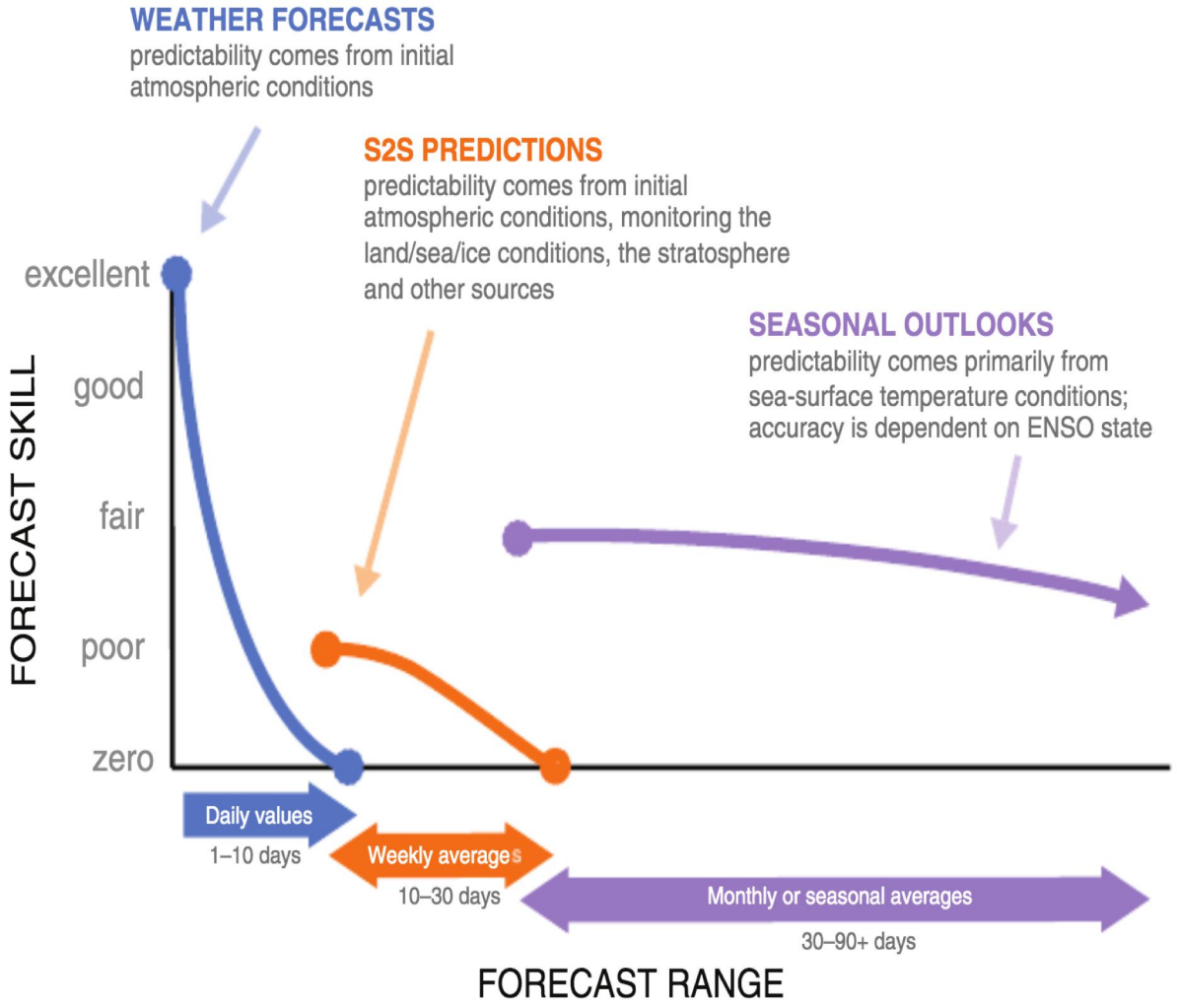
Satellite-based inundation mapping



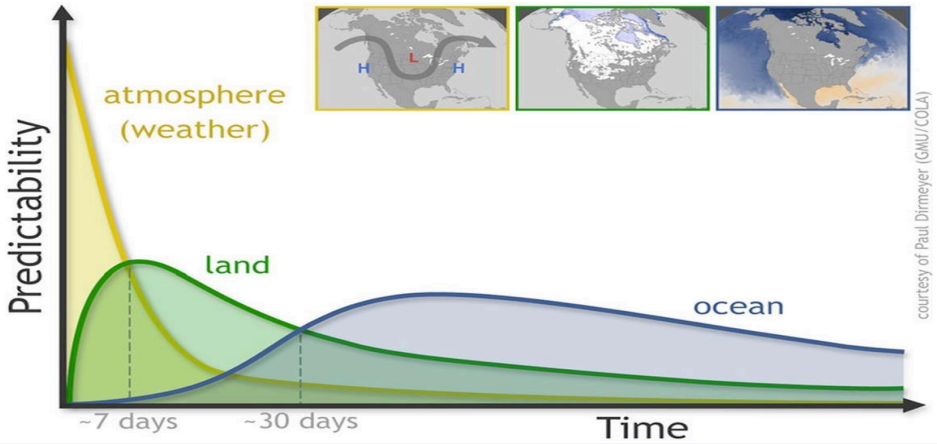


Alfieri et al., *Environmental Science and Policy, 2018*

Can we predict flooding earlier?

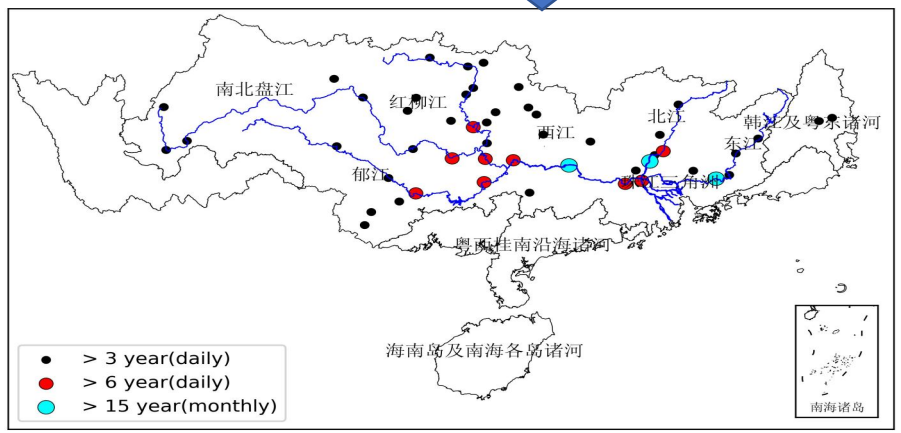


White et al., 2017

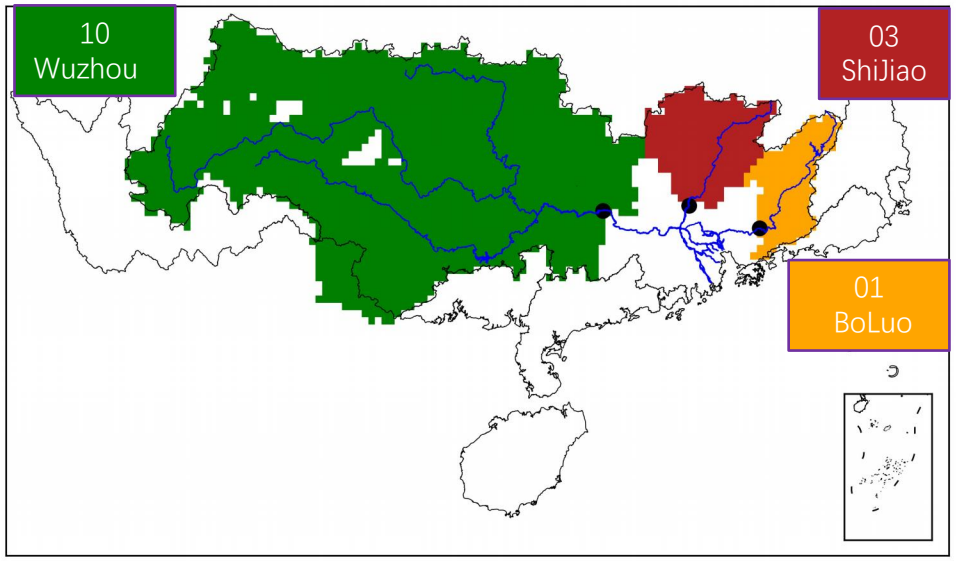


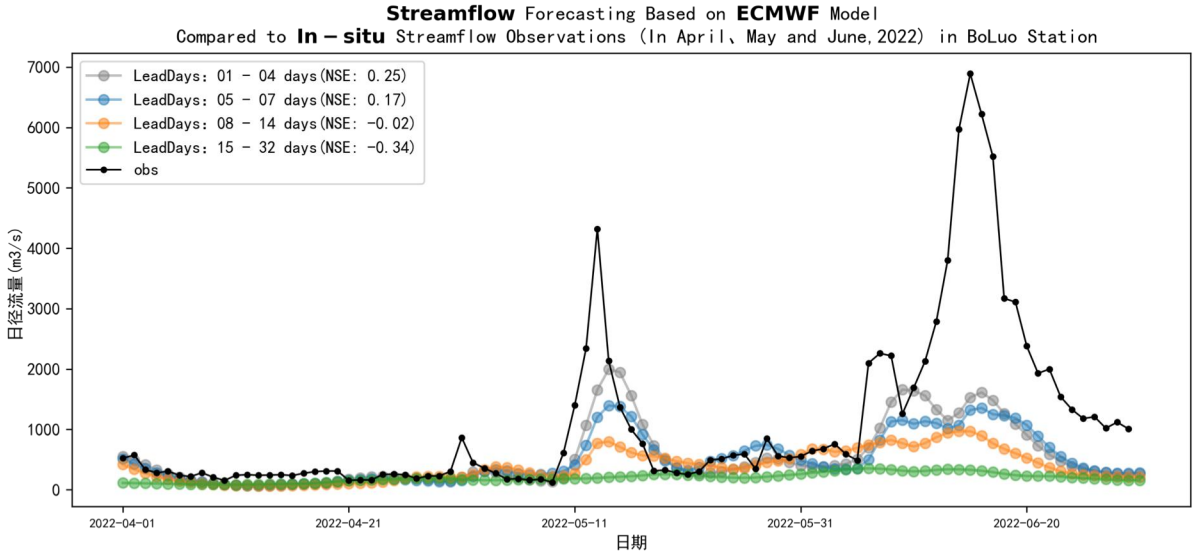
ECMWF S2S forecast

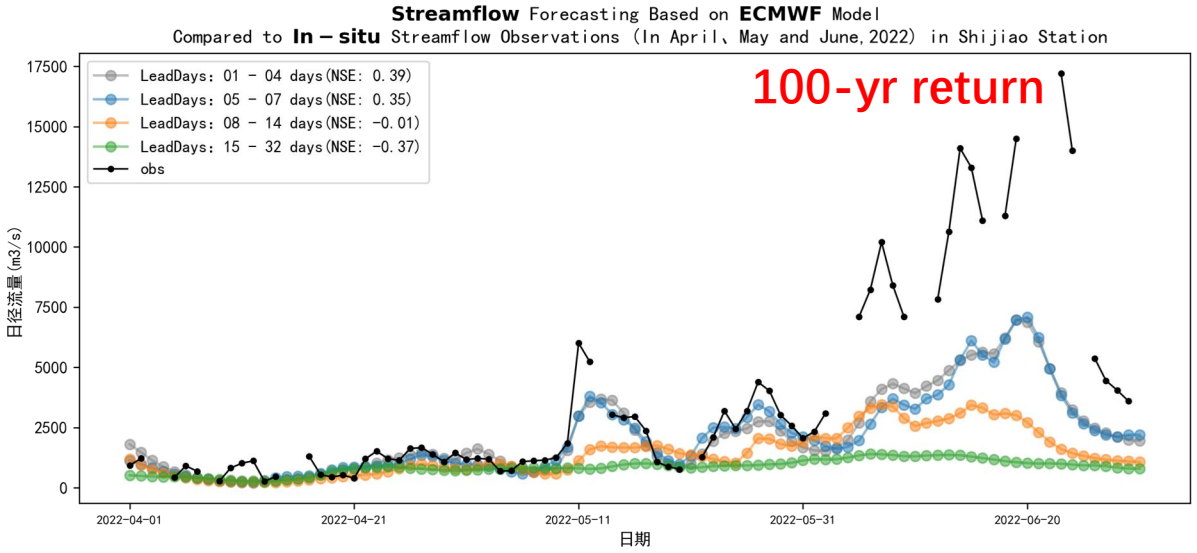
6-hourly/~50-km ,Every Monday, Thursday , **1 day - 32 days , Jan.- AUG, 2022**

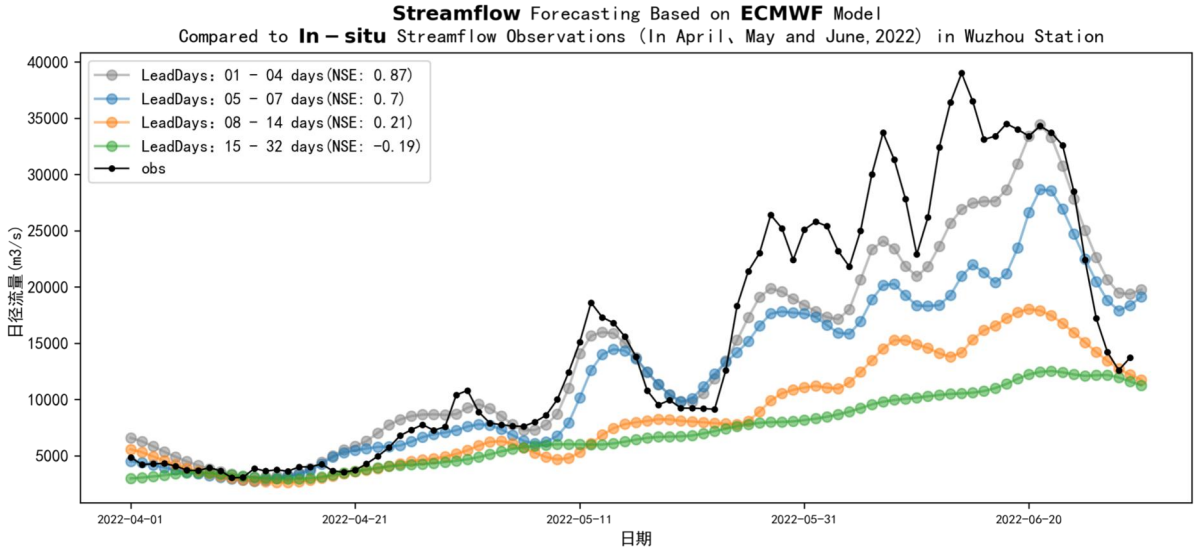


1-32 day flood forecasting @ 3 critical locations of Pearl River Basin in 2022



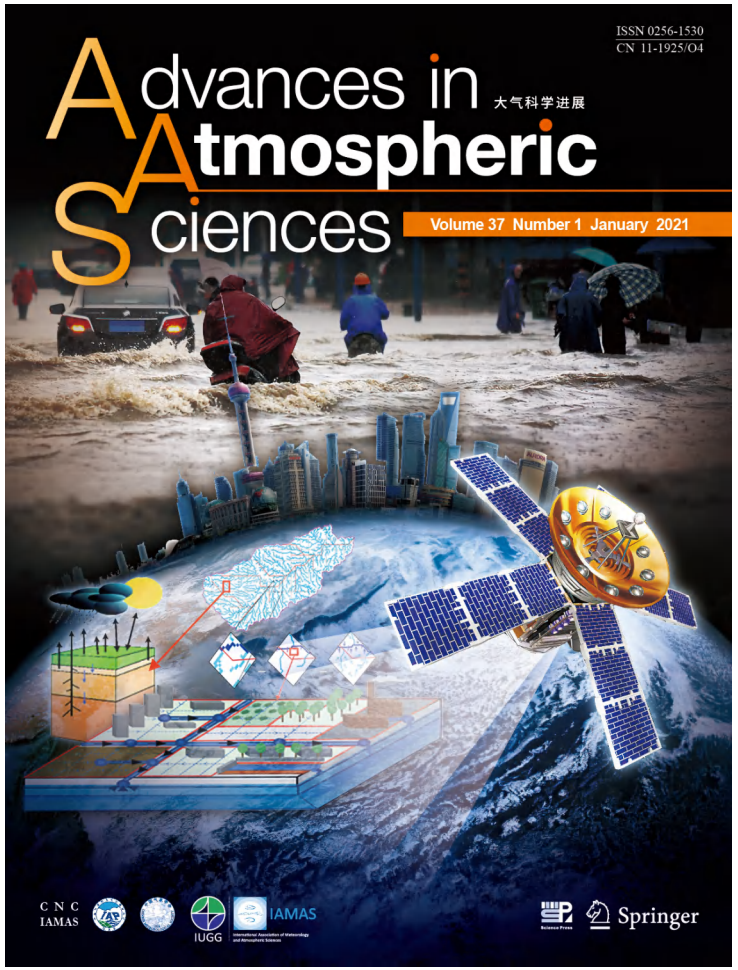






Summary

- Multi-scale floods (Flash flood, Riverine flood and Urban flood) need to and can be well addressed in one modeling framework for better response;
- **Glocal** Hydrometeorological Solution on Floods (GHS-F) has been working and applications indicate pathways for further improvement;
- Challenges ahead mainly lie in fundamental datasets: precipitation, DEM etc.



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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.

2021

"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 [illegible]versity in Guangdong, China, developed an innovative flood model linking global [illegible]ipitation patterns with localized hydrology—where water goes once it finds land

UNDRR

UNDRR EN

PreventionWeb HOME UNDERSTANDING DISASTER RISK KNOWLEDGE BASE COMMUNITY SENDAI FRAMEWORK

HOME ▸ NEWS ▸ RESEARCH BRIEFS

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

UPLOAD YOUR CONTENT

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

Marc Bruelle/Shutterstock

2021

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.

Attachments

From China's heavy precipitation i...

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Communicating the effectiveness of flood-mitigation schemes

Munich Re continues its flood mitigation work with resilience risk

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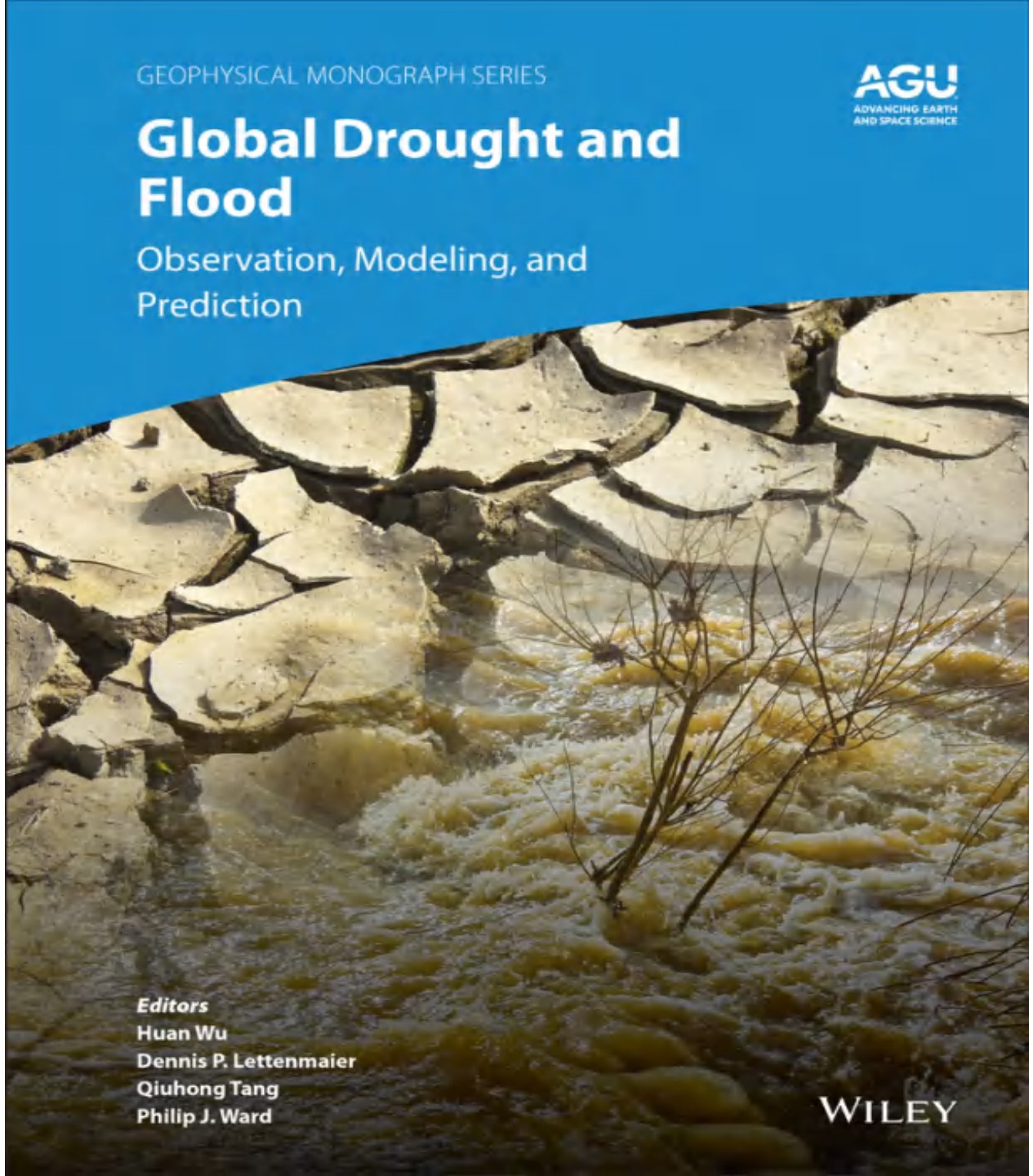
HENG
Hydrometeorological Extremes simulatioN Group

Seven Challenges in working on hydrometeorological extremes

- **Challenge 1:** Model Validation/Calibration
- **Challenge 2:** Precipitation vs Floods
- **Challenge 3:** Hydrography Uncertainty
- **Challenge 4:** Benchmark flood database
- **Challenge 5:** Flood information integration
- **Challenge 6:** Human impacts (urbanization, dam/reservoir)
- **Challenge 7:** Flood projection with climate change and LUCC

HENG
Hydrometeorological Extremes simulatioN Group

Thanks



- **2021 AGU Monograph《Global Drought and Flood: Observation, Modeling and Prediction》**
- **AGU recommended COP26 exhibition book (only 4)**