中国科学院地理科学与资源研究所
Institute of Geographic Sciences and Natural Resources Research, CAS

HEPEX
a community of research and practice to advance hydrologic ensemble prediction

A Hydrological Monitoring and Forecast System over China

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Background

- **The hydrological extremes are frequent and costly in China.**

Farmland suffers from the worst drought in 60 years in north China's Inner Mongolia Autonomous Region, June 16, 2017

The corn has grown to only half its normal height. Farmers and herders become desperate to get water to farmlands, grasslands, animals and their households.

Background

July 2, 2017
Changsha, Hunan

July 2, 2017
Xiangjiang River
Water level 39.21 m, well above warning level of 36 m.

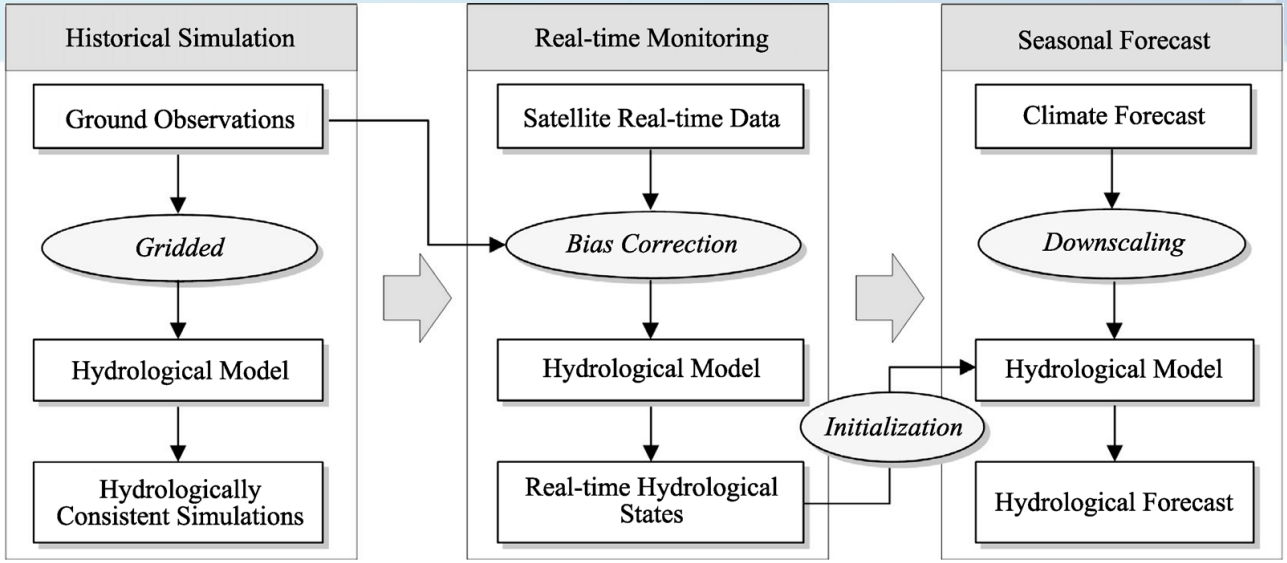
July 1, 2017
Huangcai Town of Ningxiang, Hunan.

July 1, 2017
Downtown Ningxiang, Hunan, China.

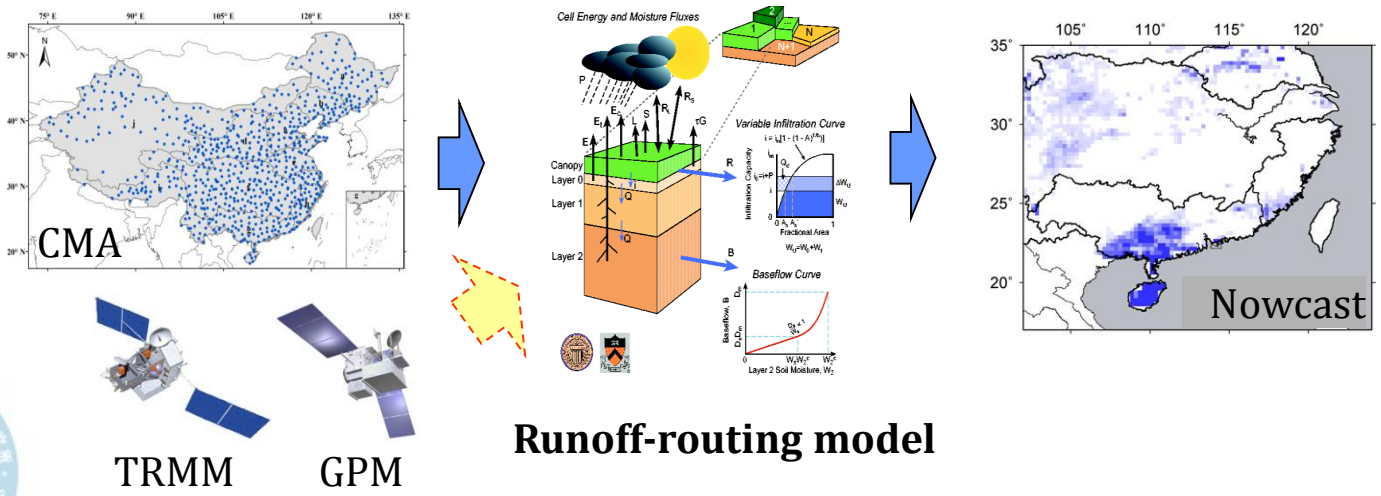
Affected population 815 thousand, 44 people deaths, direct economic loss about CN ¥9 billion.

Flood is a leading natural disaster with worldwide, significant, negative social-economic impacts. Floods had killed over 59,000 people, affected about 0.9 billion people and cost an estimated $340 billion (2014 prices) in the past decade.

Hydrological Monitoring and Forecast System

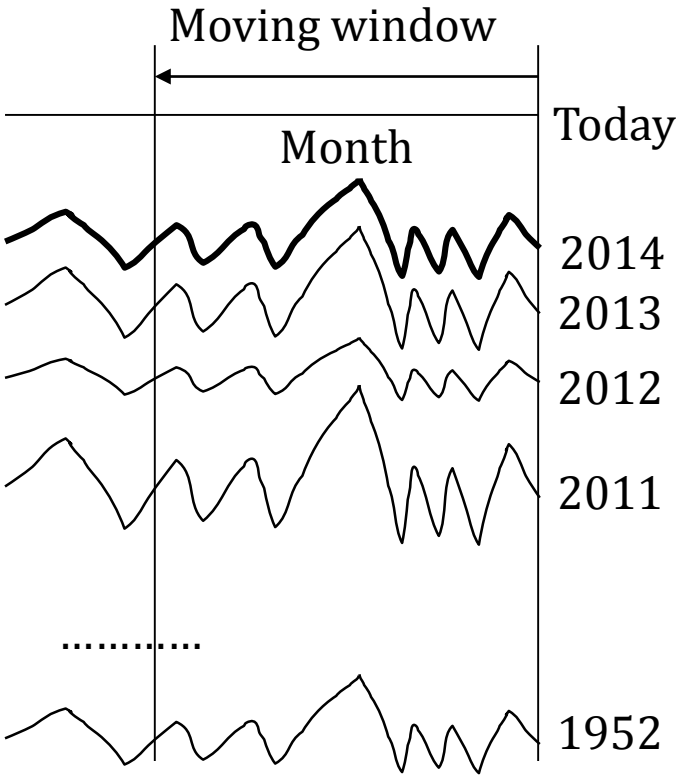


Hydrological monitoring and forecast framework for China



Tang et al. JGS, 2016

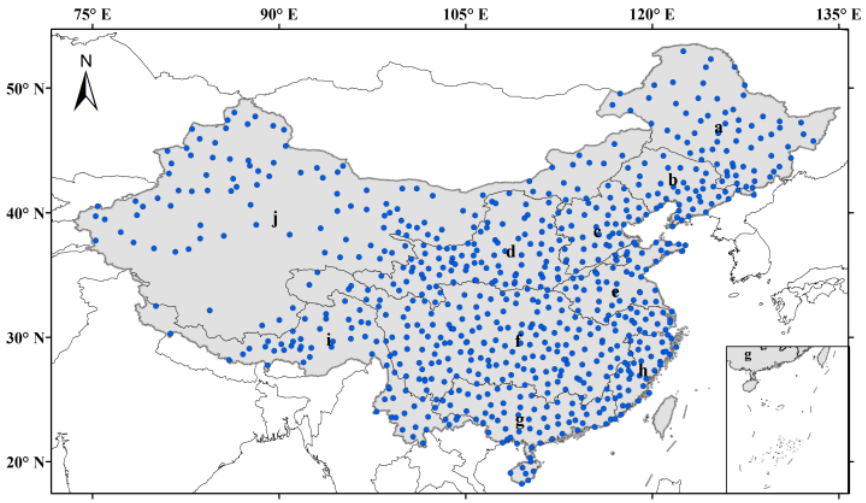
Long-term model simulations



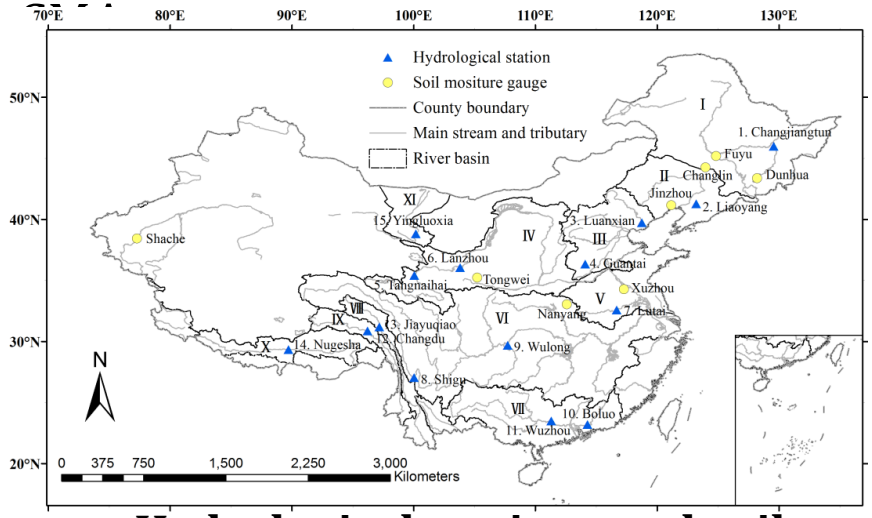
Long-term simulation is required for monitoring:

- Model calibration and validation;
- A reference for current hydrological assessment.

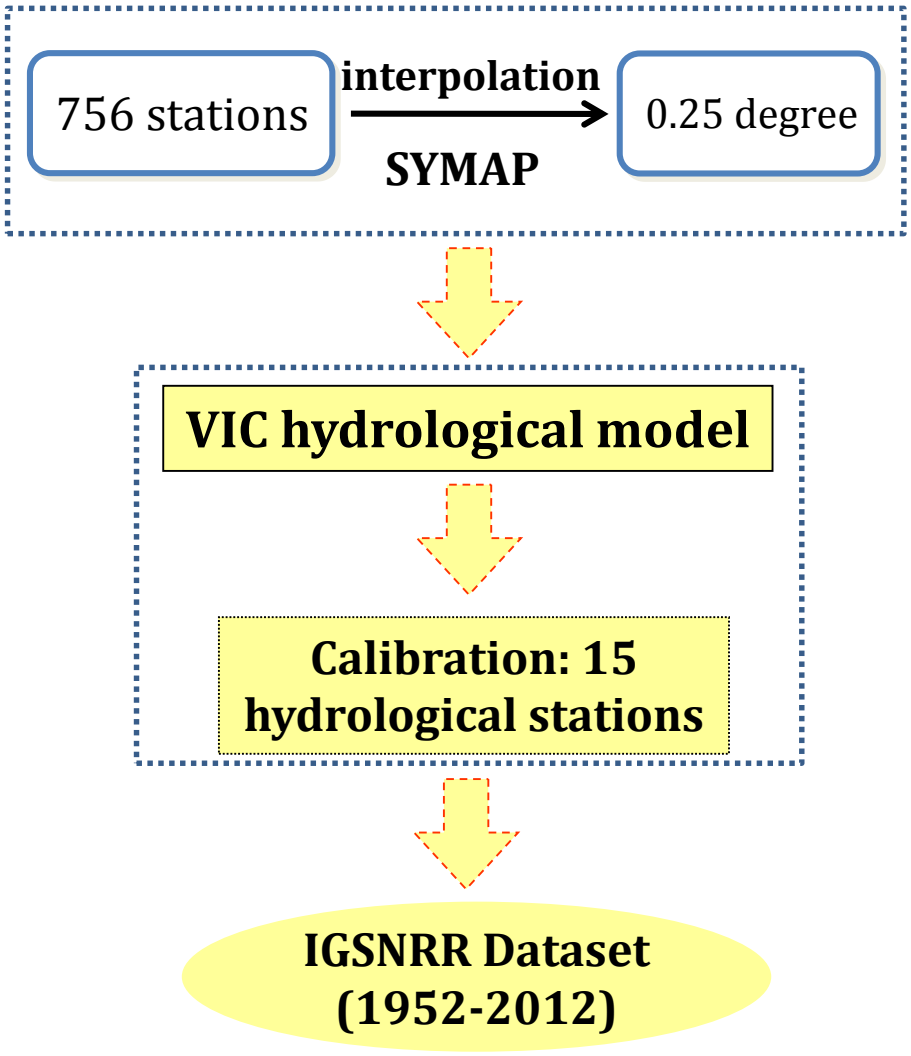
A 60-year dataset of hydrological fluxes and states



Meteorological stations

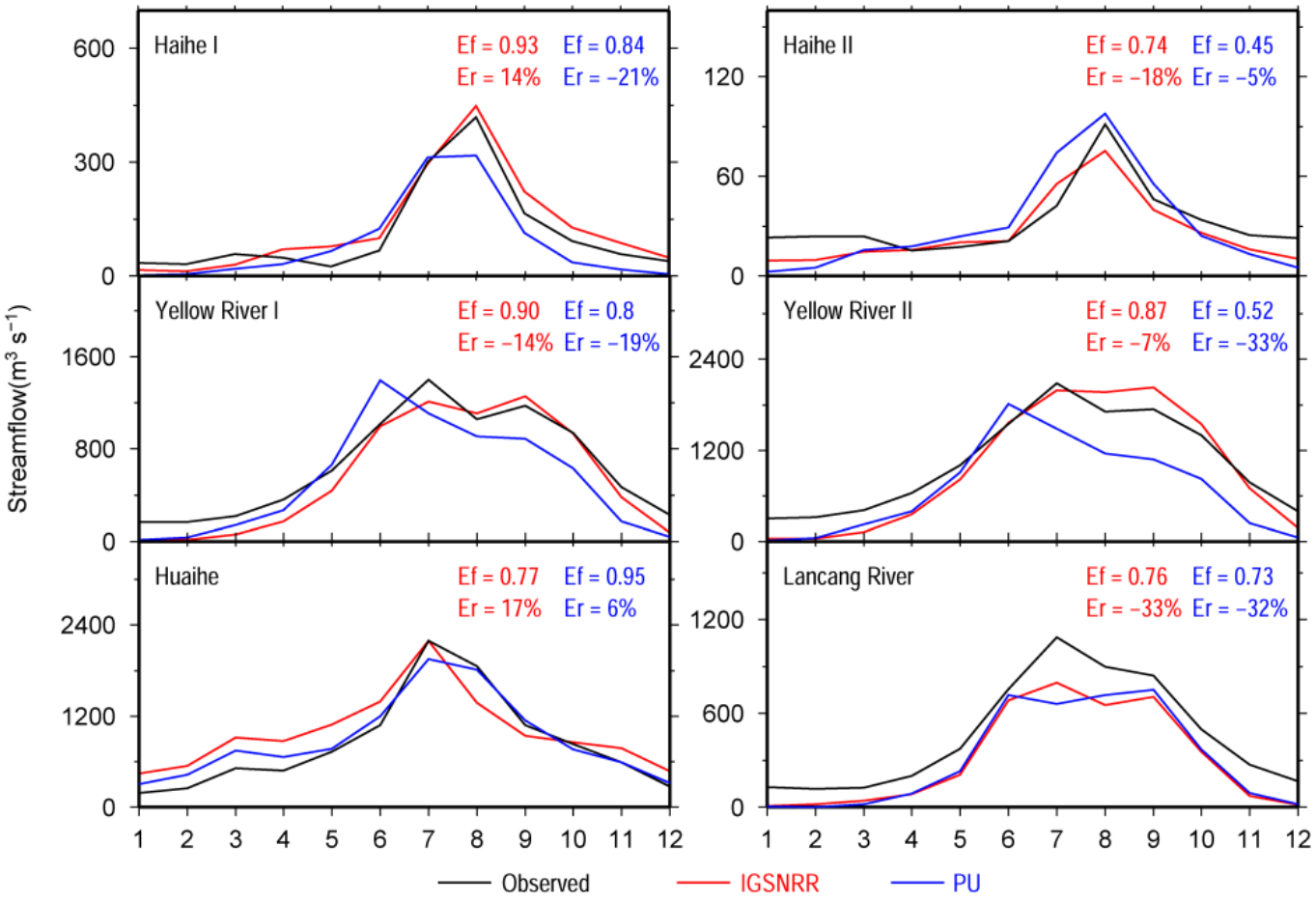


Hydrological stations and soil moisture observations



Zhang and Tang et al., JHM, 2014

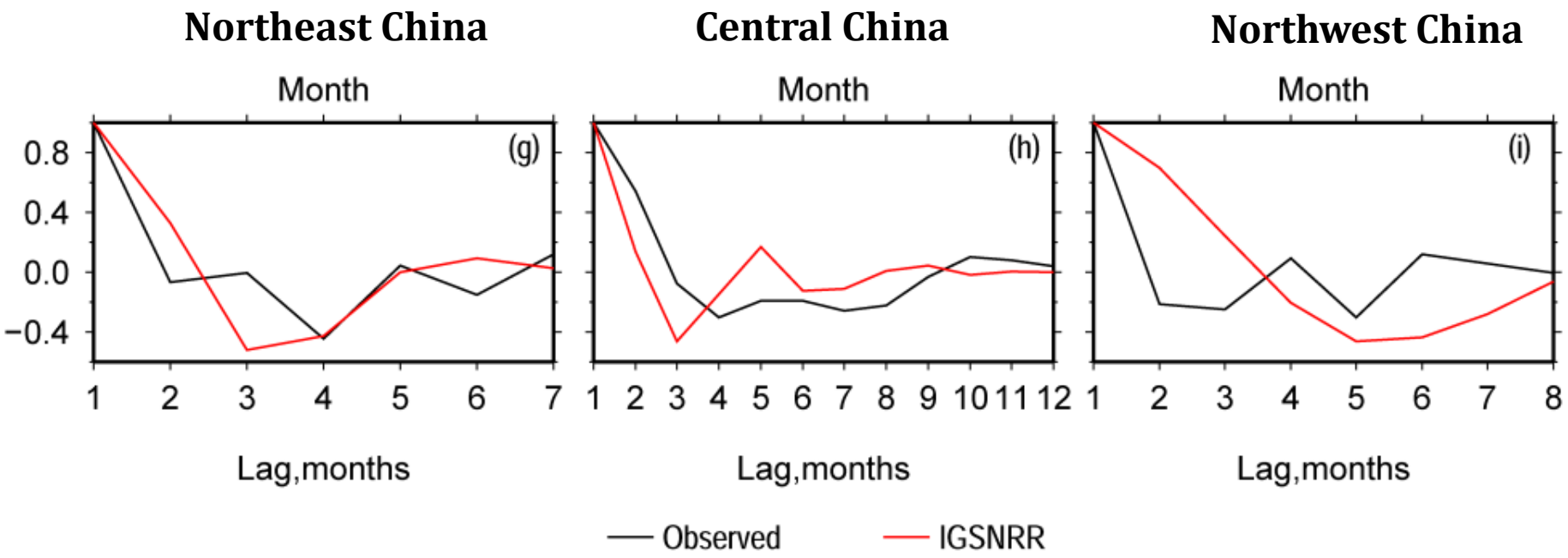
Model validation (1981-2000)



Red: IGSNRR
Blue: PU global data
Black: Observations

IGSNRR can reproduce the hydrographs better in China partly due to its inclusion of more ground observations.

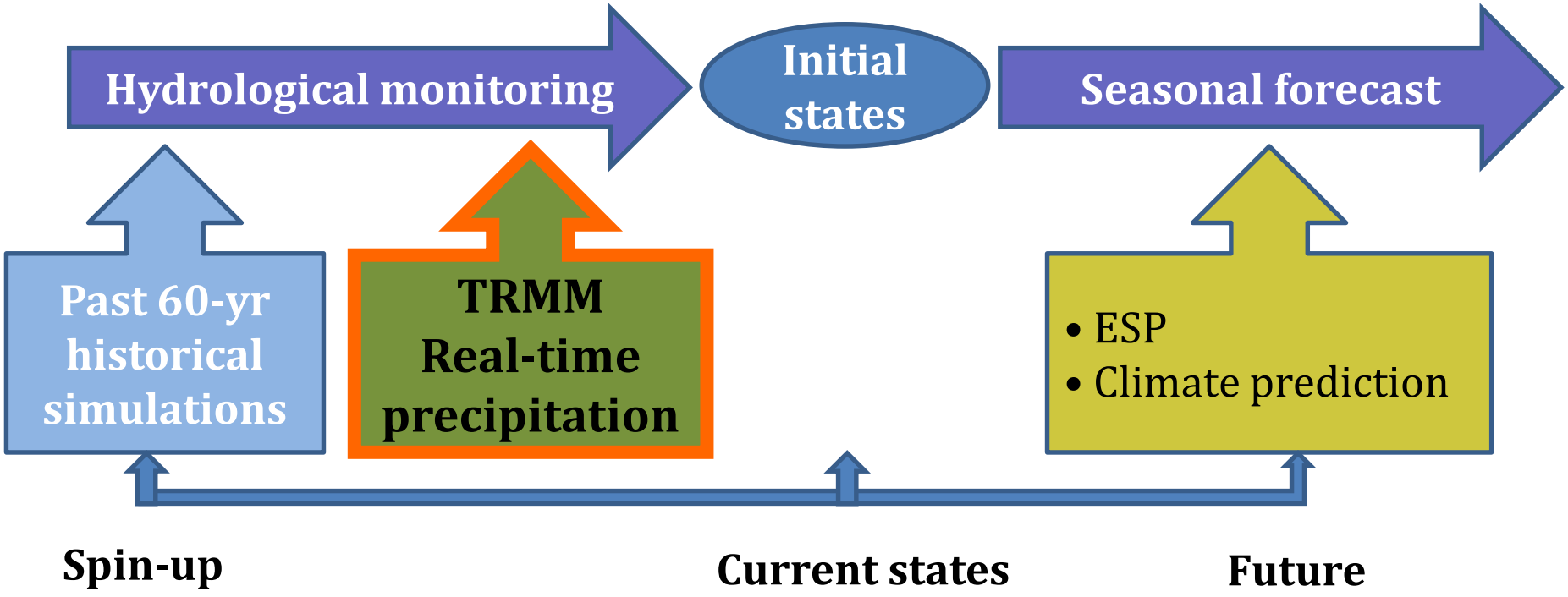
Soil moisture: autocorrelations



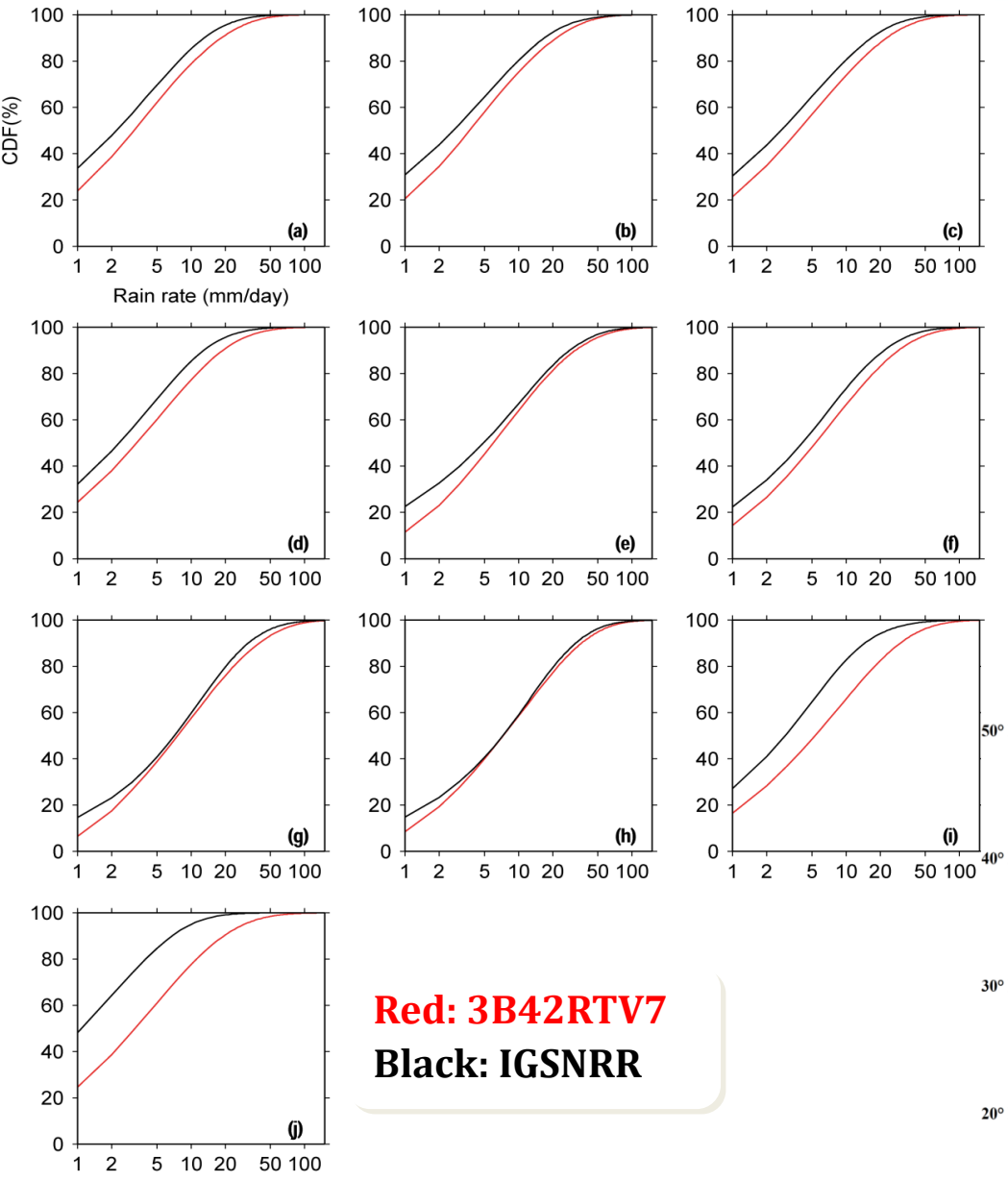
Autocorrelation of soil moisture anomalies

Zhang and Tang et al., JHM, 2014

Satellite-assisted hydrological monitoring



Comparison between TRMM and ground observations

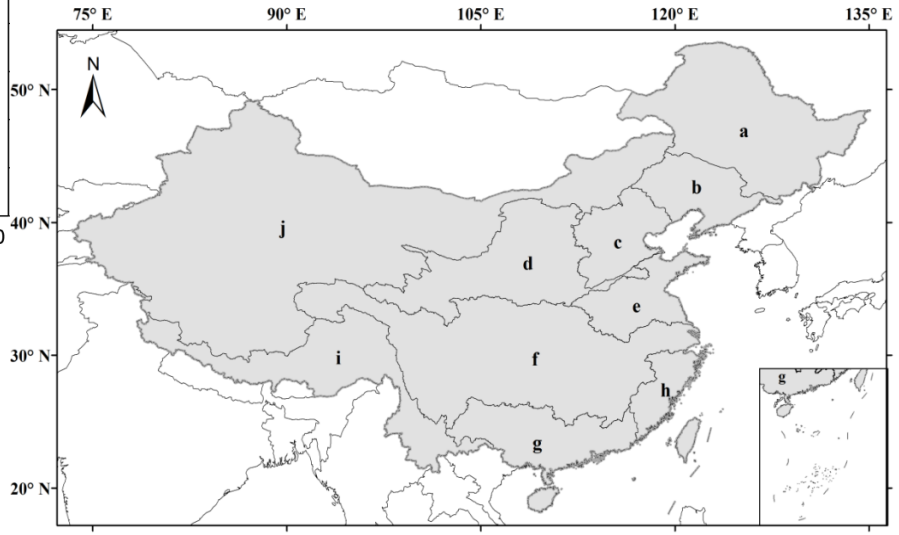


Red: 3B42RTV7

Black: IGSNRR

TRMM real-time precipitation (3B42RTV7) overestimates precipitation.

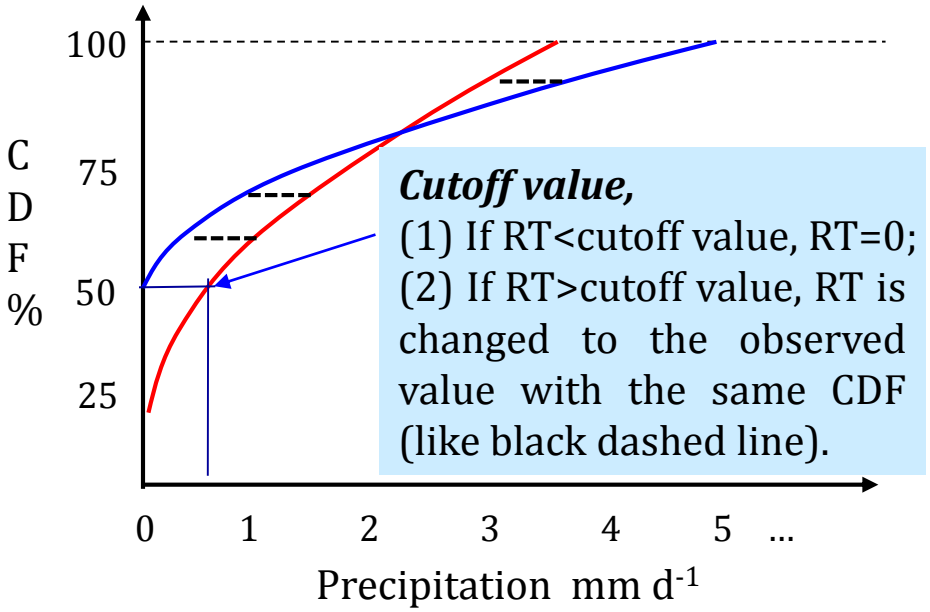
10 large river basins in China



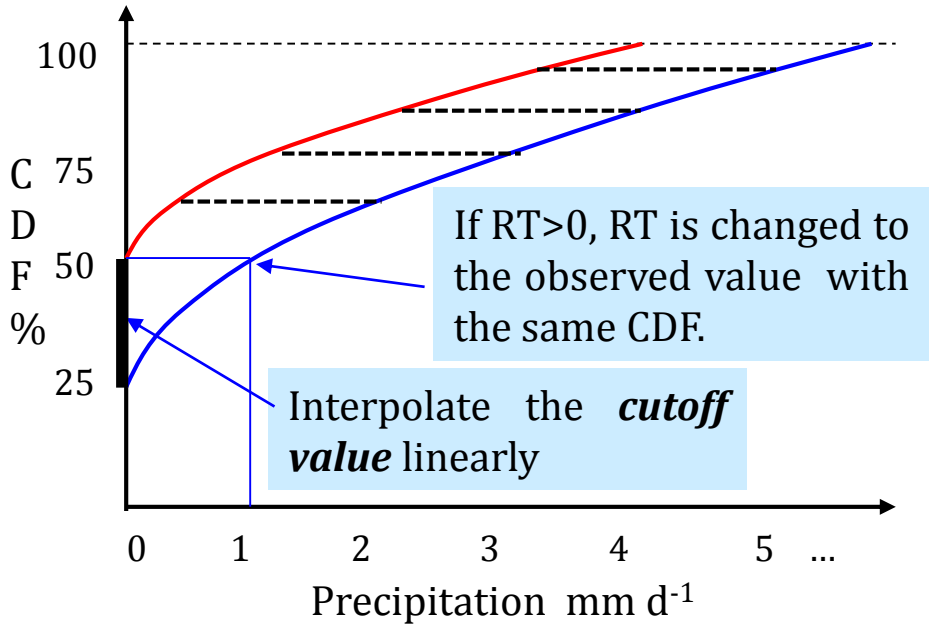
A simple adjustment method

- **Method:** Cumulative Density Function (CDF) mapping
- **Training Period:** 2000.03-2010.12
- **Validation Period:** 2010.01-2013.12

1: RT frequency >= observed

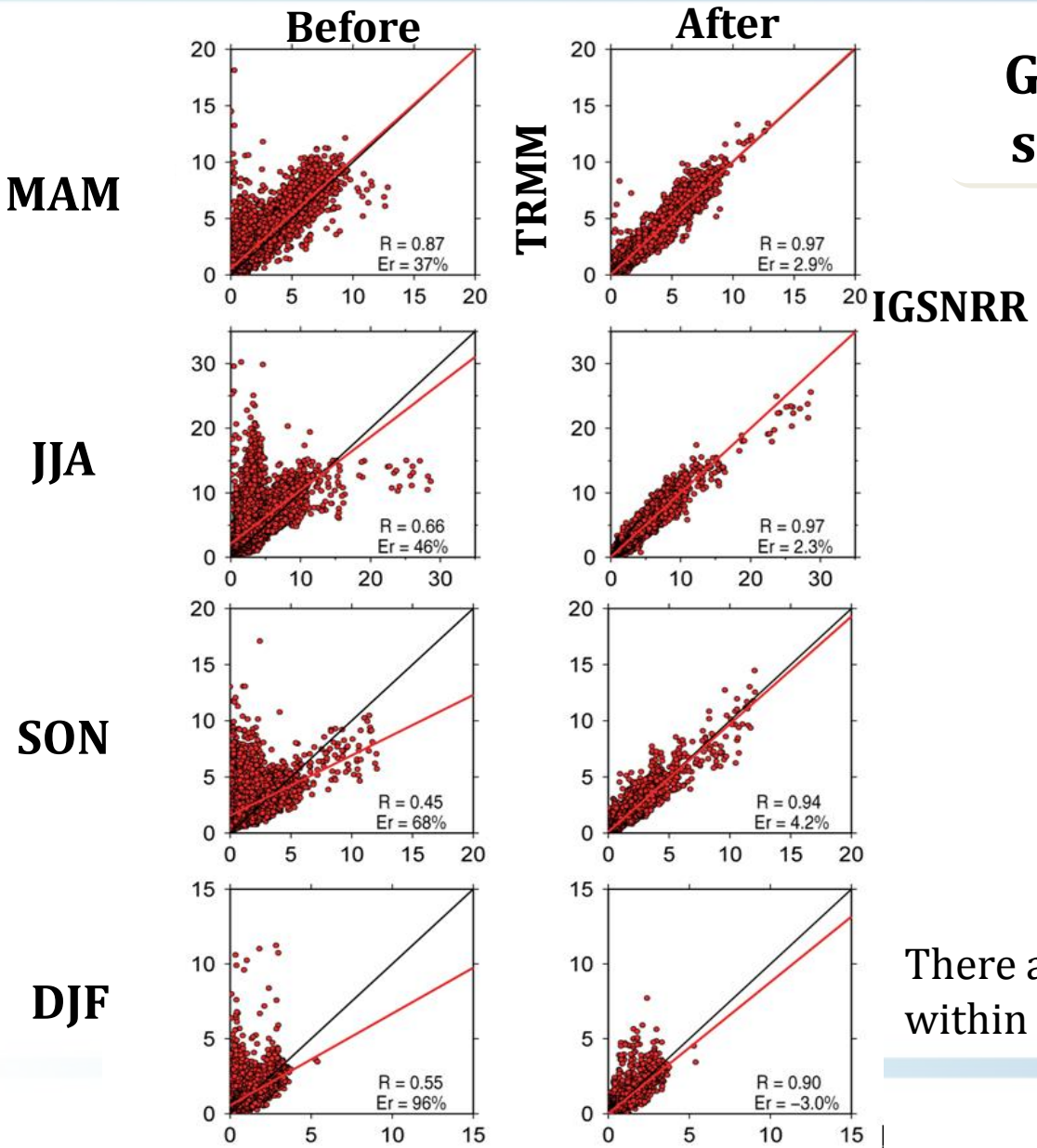


2: RT frequency < observed



3B42RTV7 IGSNRR

TRMM precipitation after adjustment

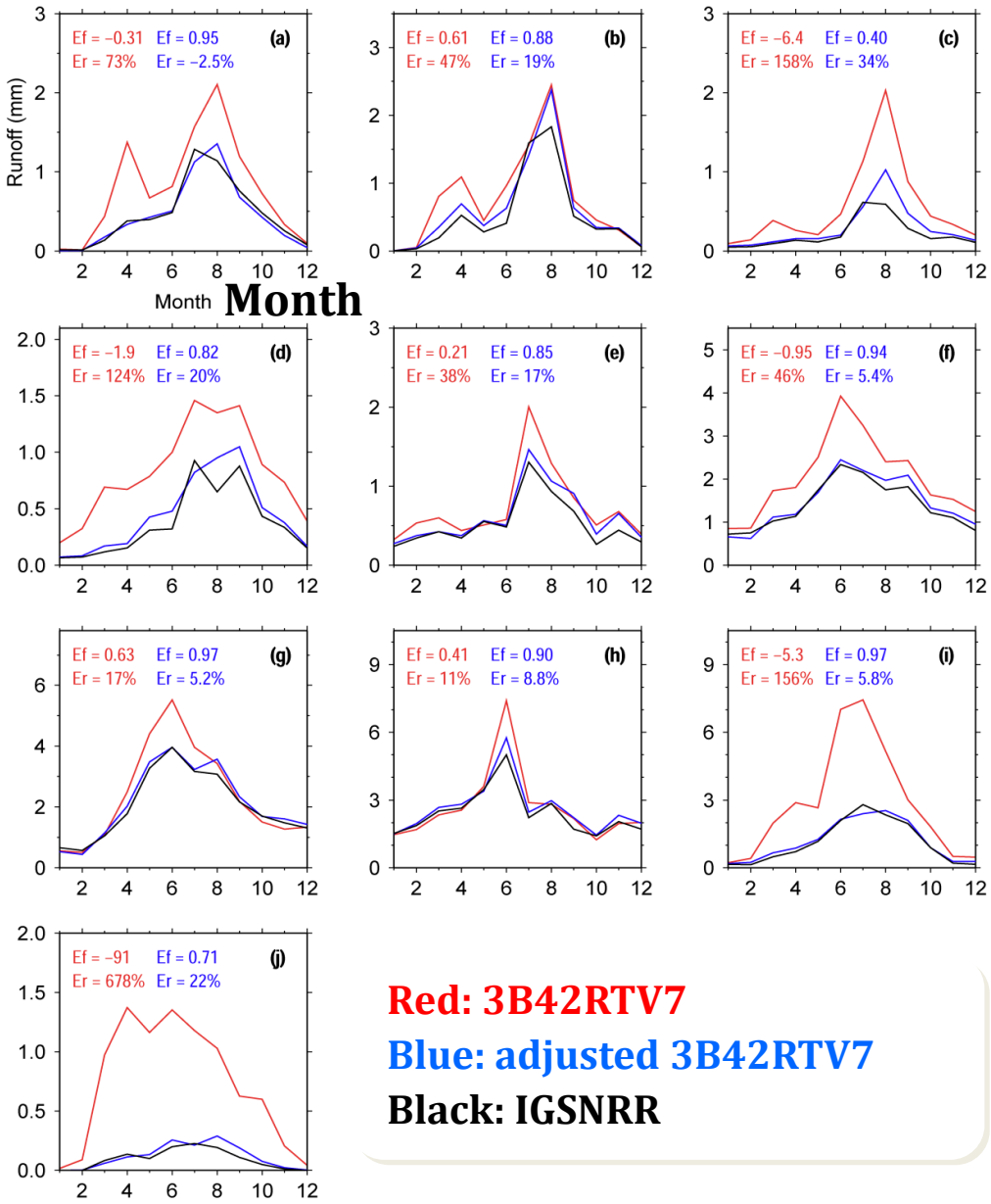


Grid-by-grid scatter plots

There are 15402 grids within each figure

Hydrographs at the basins

Runoff (mm)

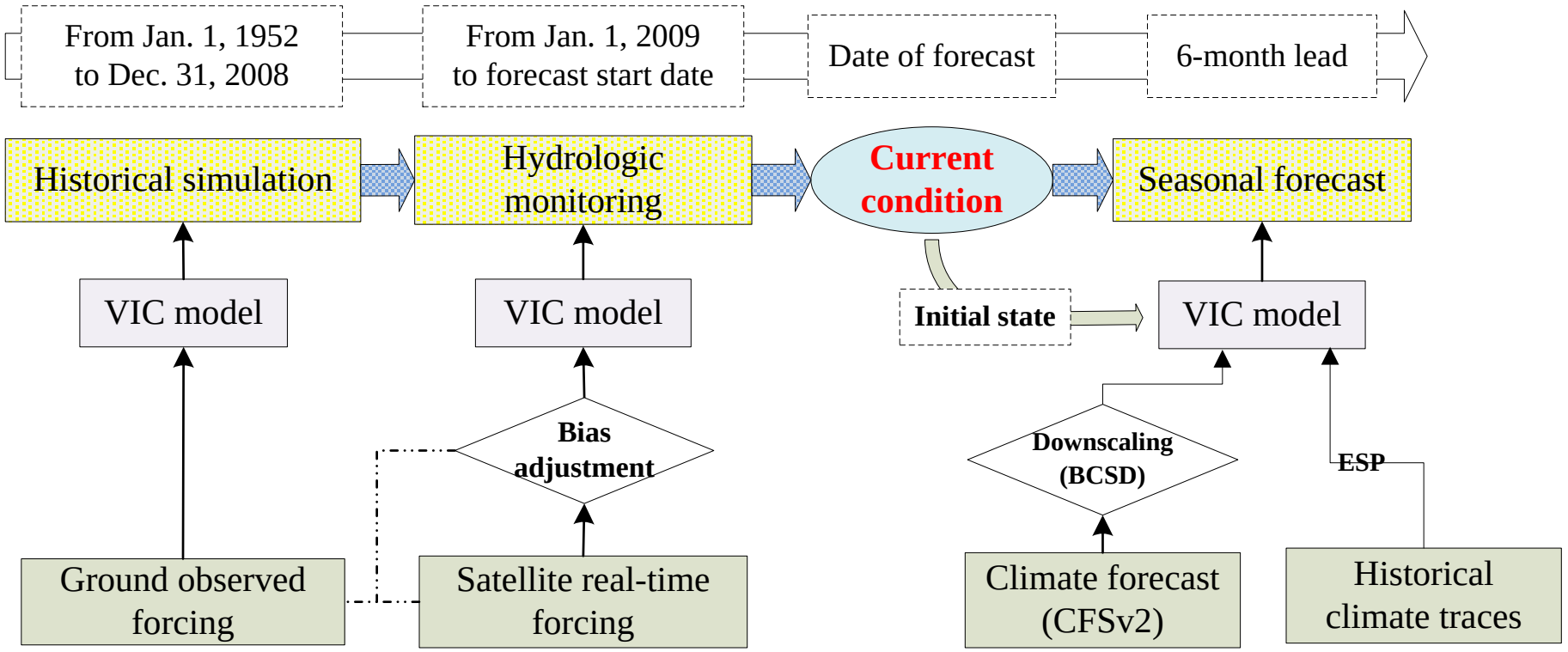


Red: 3B42RTV7

Blue: adjusted 3B42RTV7

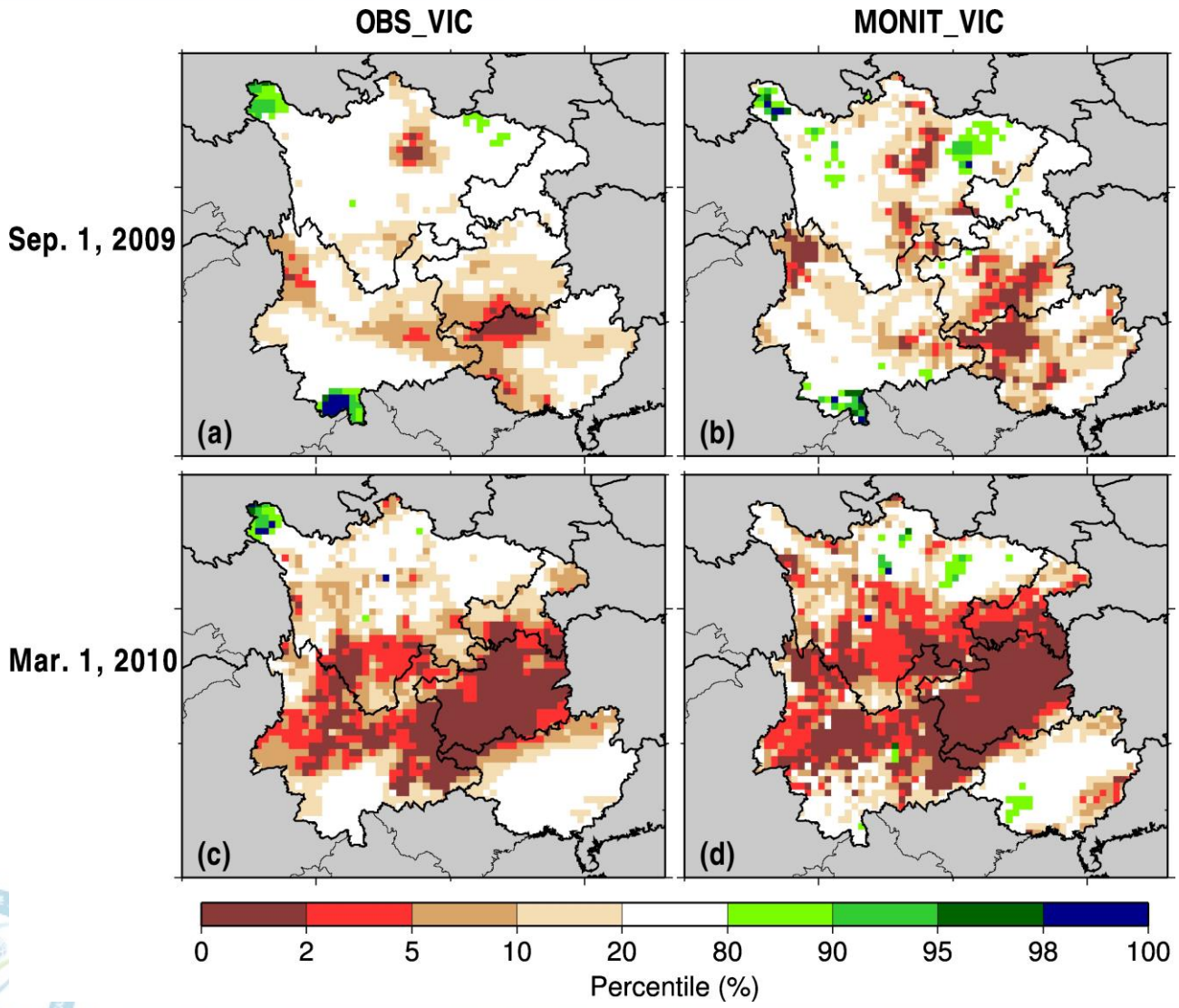
Black: IGSNRR

From monitoring to forecasting



NECP Climate Forecast System version 2 (CFSv2) & Ensemble Streamflow Forecast (ESP)

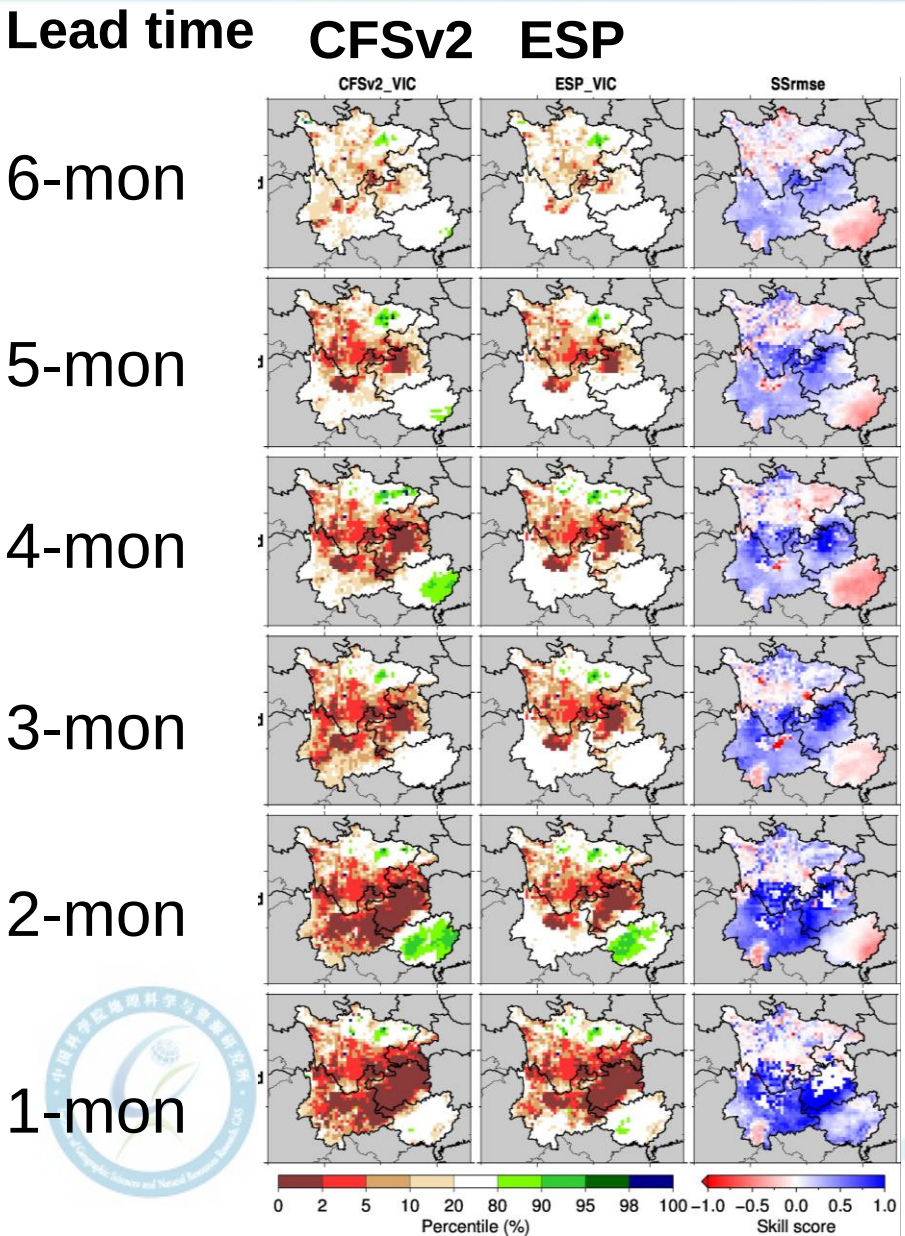
Soil moisture drought monitoring

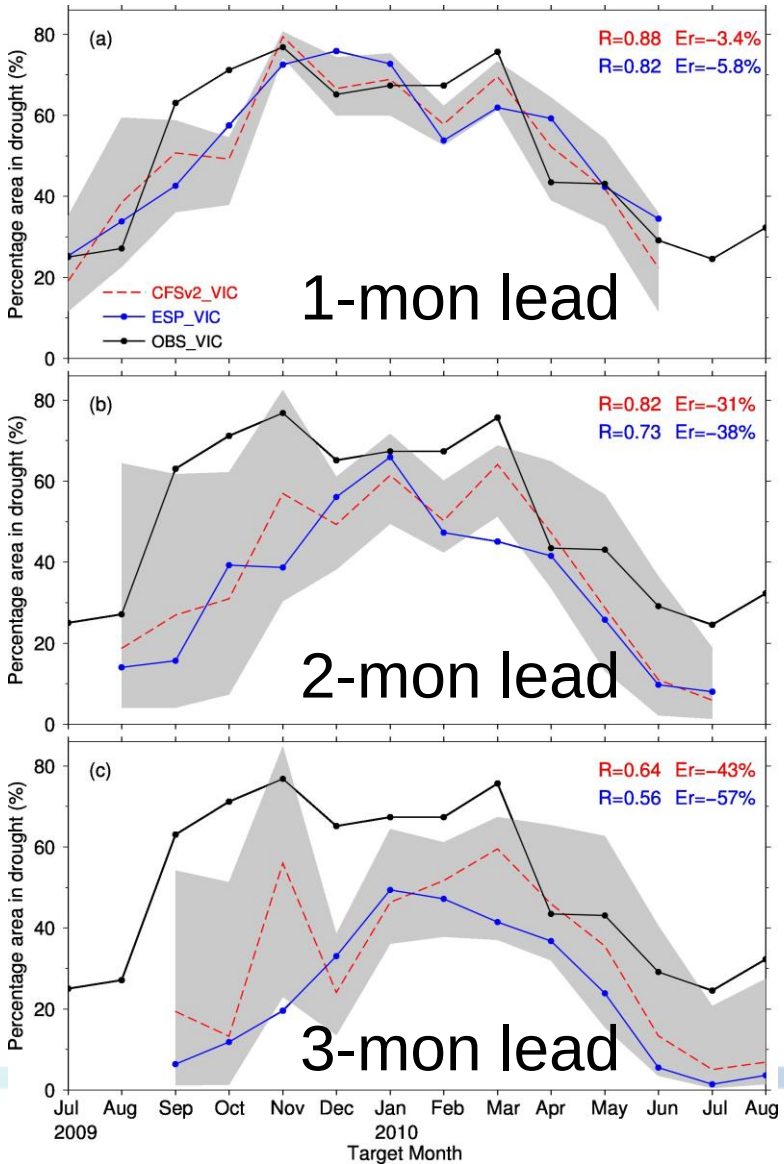


Southwest China

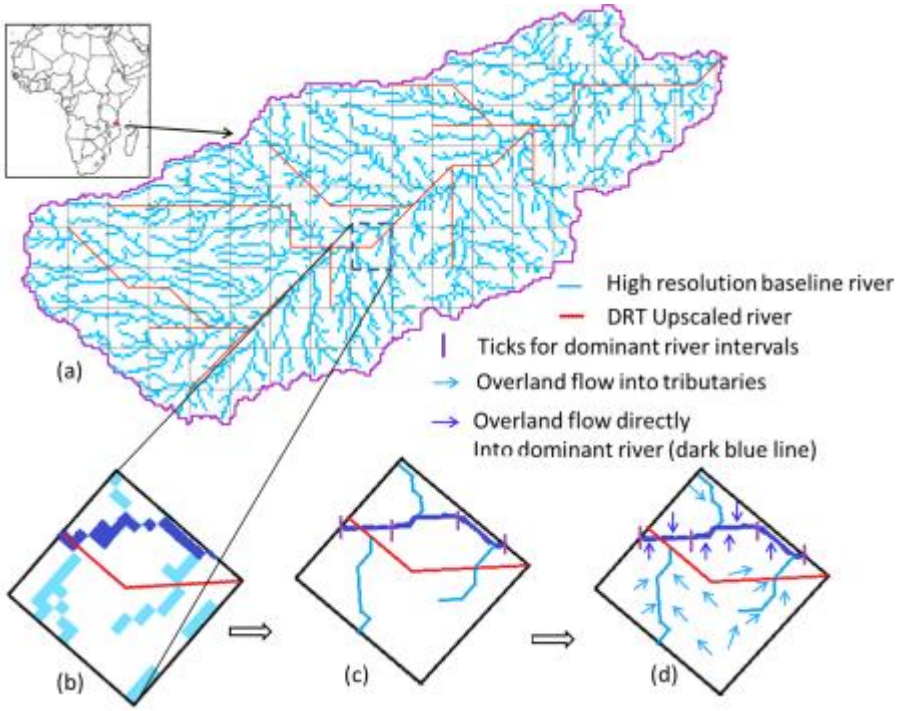
Zhang et al., 2015

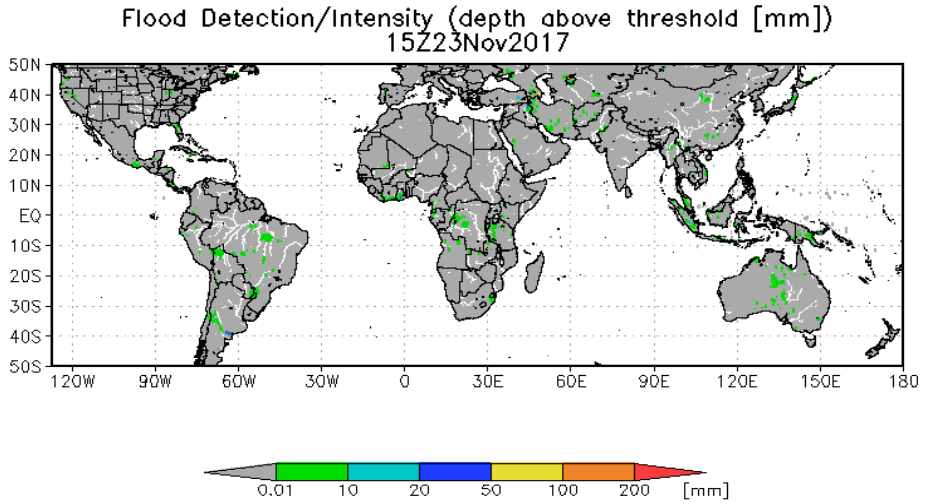
Drought forecast (March 2010)





Are the system useful for flood simulation?



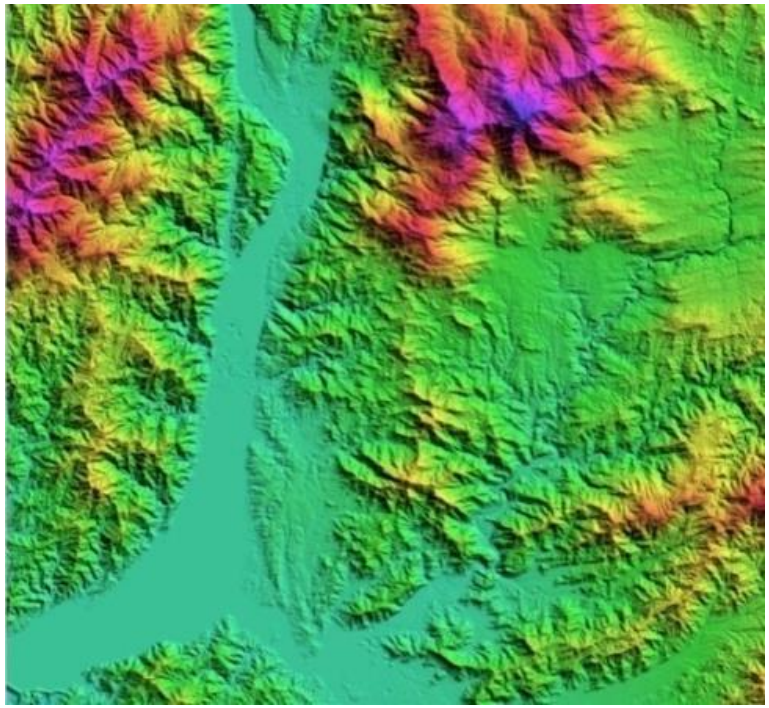


Global Flood Monitoring System (GFMS)

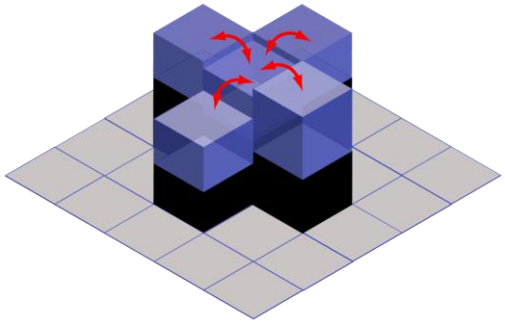
Although the system gives valuable flood warning information at large scale, there is still huge gap to fit the needs of flood prevention agency. The agencies usually ask for flood risk assessment for a city or a village.

Wu et al. WRR, 2014

High resolution simulation over a natural surface



High resolution DEM



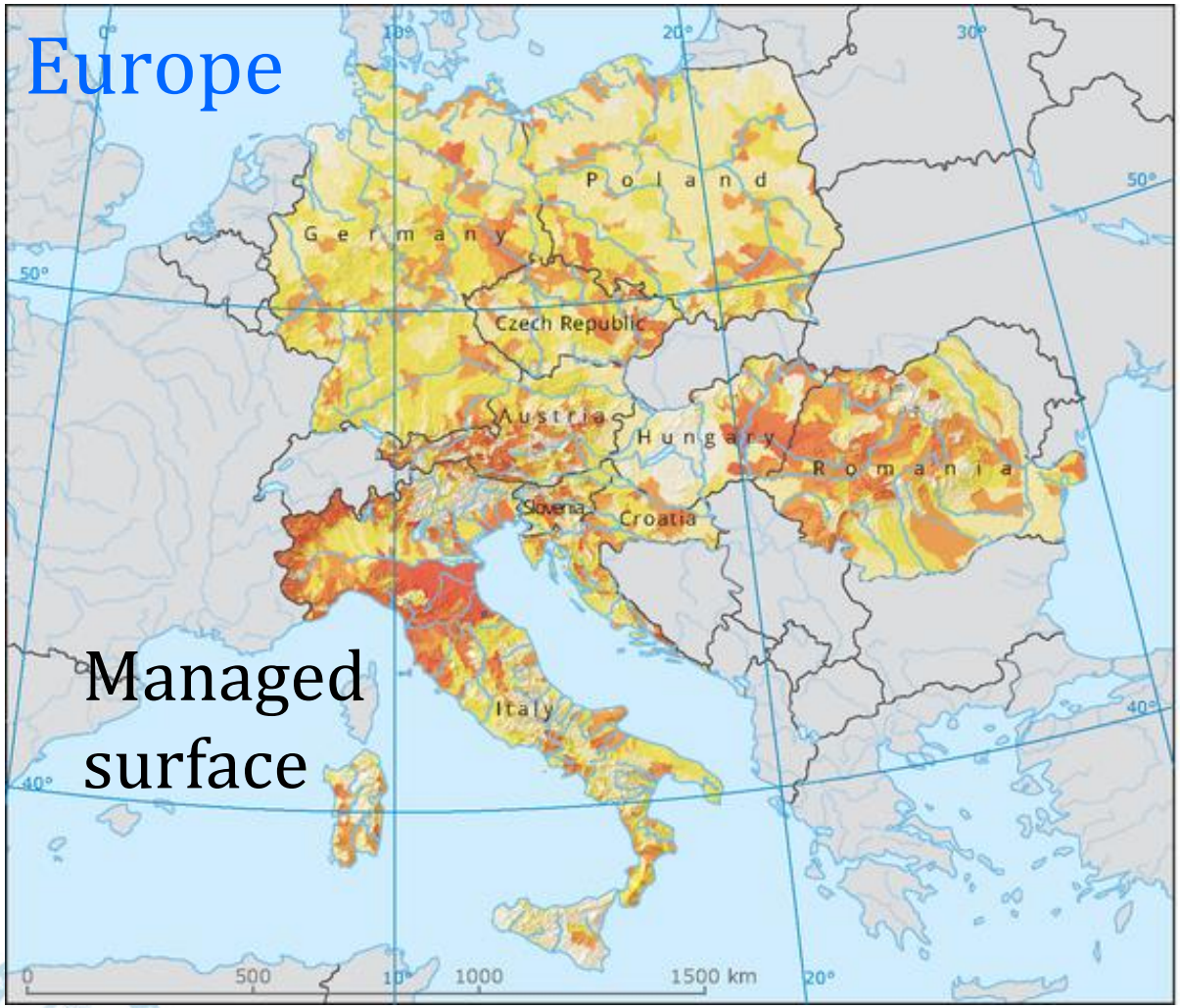
2D hydrodynamic equations

Accelerated by single/multiple GPUs

High-Performance Integrated hydrodynamic Modelling System (HI-PIMS)

Liang et al. 2016

A large portion of people lives in flood-prone area, with a managed surface



Share of population living in the floodplain areas

Percentage

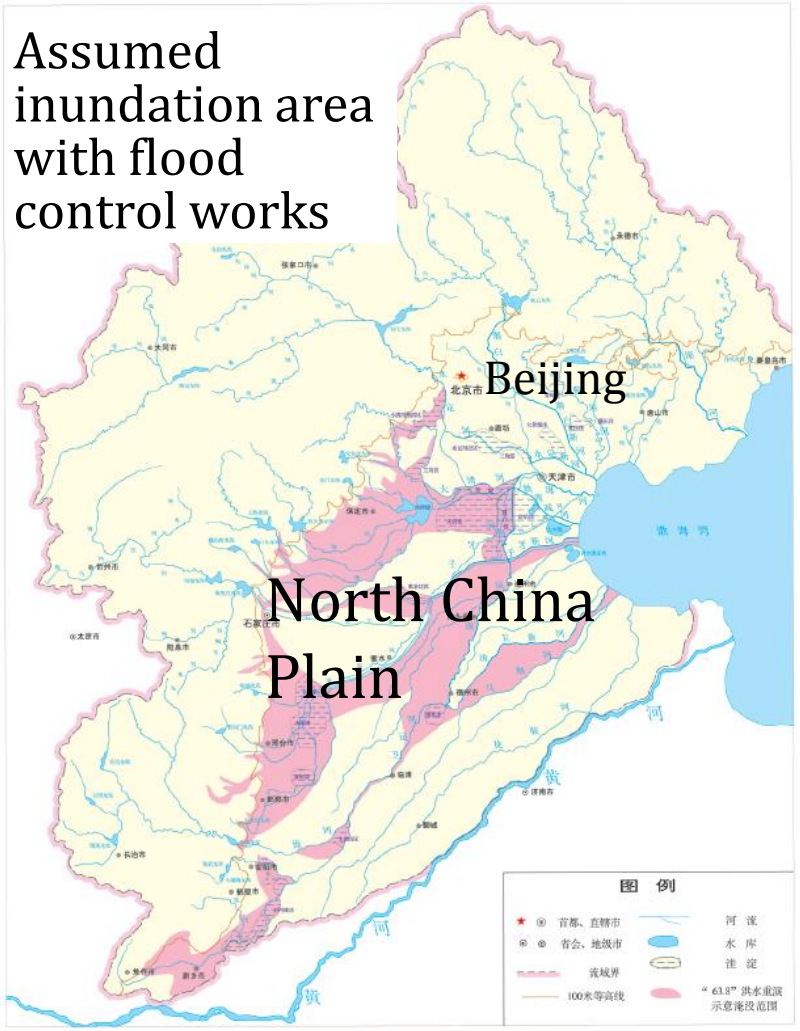
- 0
- 0–2
- 2–5
- 5–10
- 10–25
- 25–50
- 50–100
- Outside coverage

Note

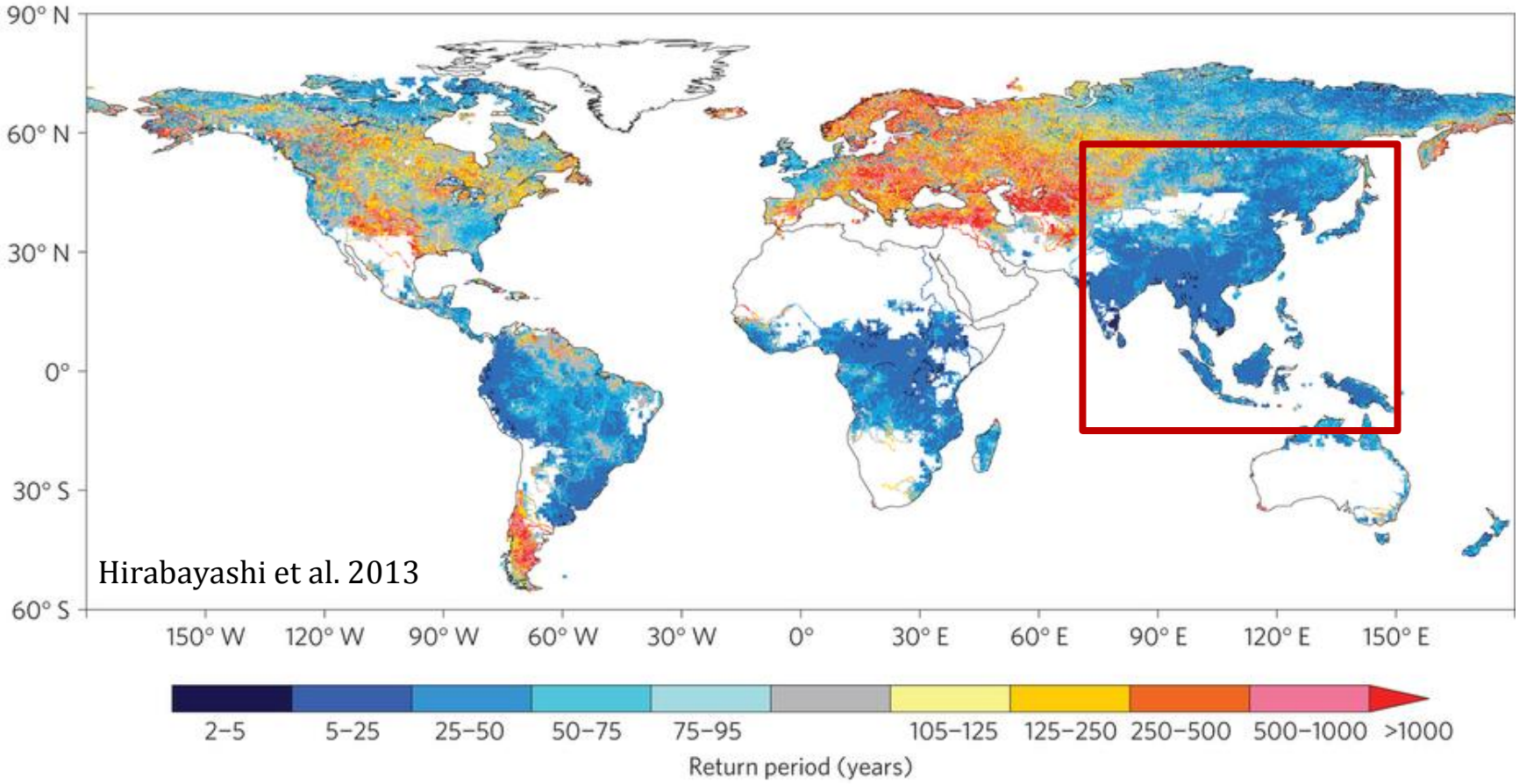
Based on the EU Floods Directive Flood Hazard Mapping, medium scenario

European Environment Agency

Flood risk with flood control measures at Haihe River Basin, August 1963 flood

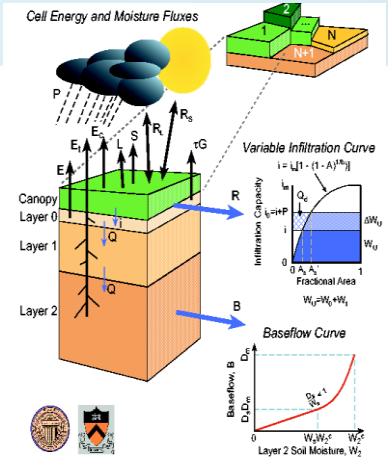


Increasing flood frequency under climate change



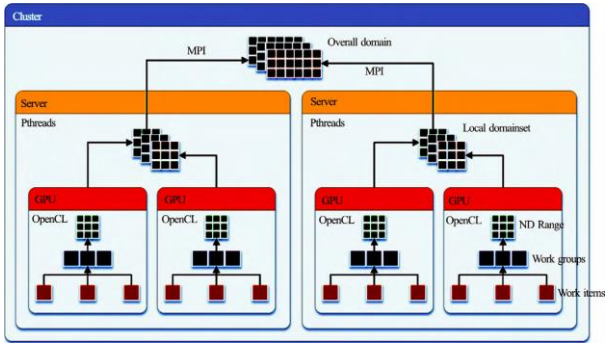
Projected change in flood frequency. Multi-model median return period (years) in 21C for discharge corresponding to the 20C 100-year flood.

Modelling with flood control measures



VIC hydrologic model

- Variable Infiltration Capacity hydrologic model
  - Subgrid heterogeneity
  - Multiple soil layers with variable infiltration
- Provide the discharge into the Baiyangdian Lake



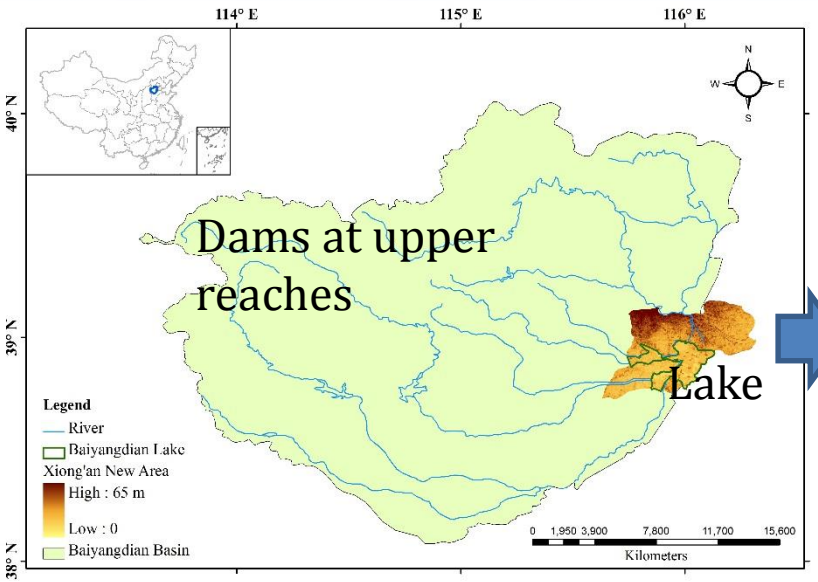
Hydrodynamic modelling (HI-PIMS)

- Solving full 2D hydrodynamic equations
- State of the art *Godunov-type finite volume method*
- Depth positivity preservation method + Local boundary modification method
- Accelerated by single/multiple GPUs

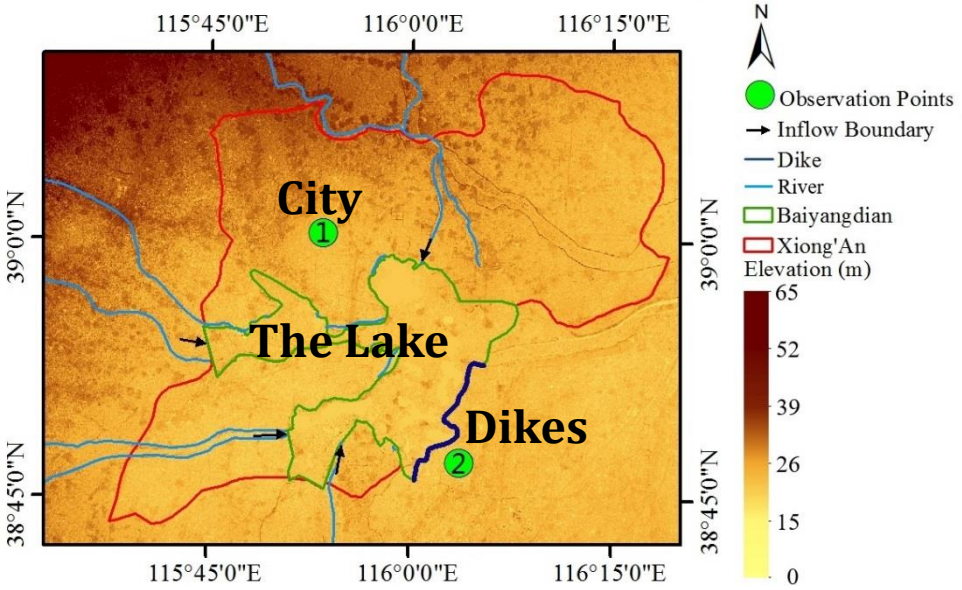
Flood modelling using an integrated approach of hydrologic and hydrodynamic modelling.

Liang et al. 1994; Liang et al. 2016

Modeling with flood control measures



The Baiyangdian Lake Basin



The Xiong'an New Area

Established in April 2017, the Xiong'an area is located about 100 km southwest of Beijing. Its main function is to serve as a development hub for the Beijing-Tianjin-Hebei economic triangle.

Experimental design

- **Exp 1: Flood risk of a historical 50-year flood (the August 1963 flood)**
- **Exp 2: Present flood risk, using the same historical 50-year flood with the flood control works**
- **Exp 3: A future 50-year flood with the heightened dike and reservoirs**

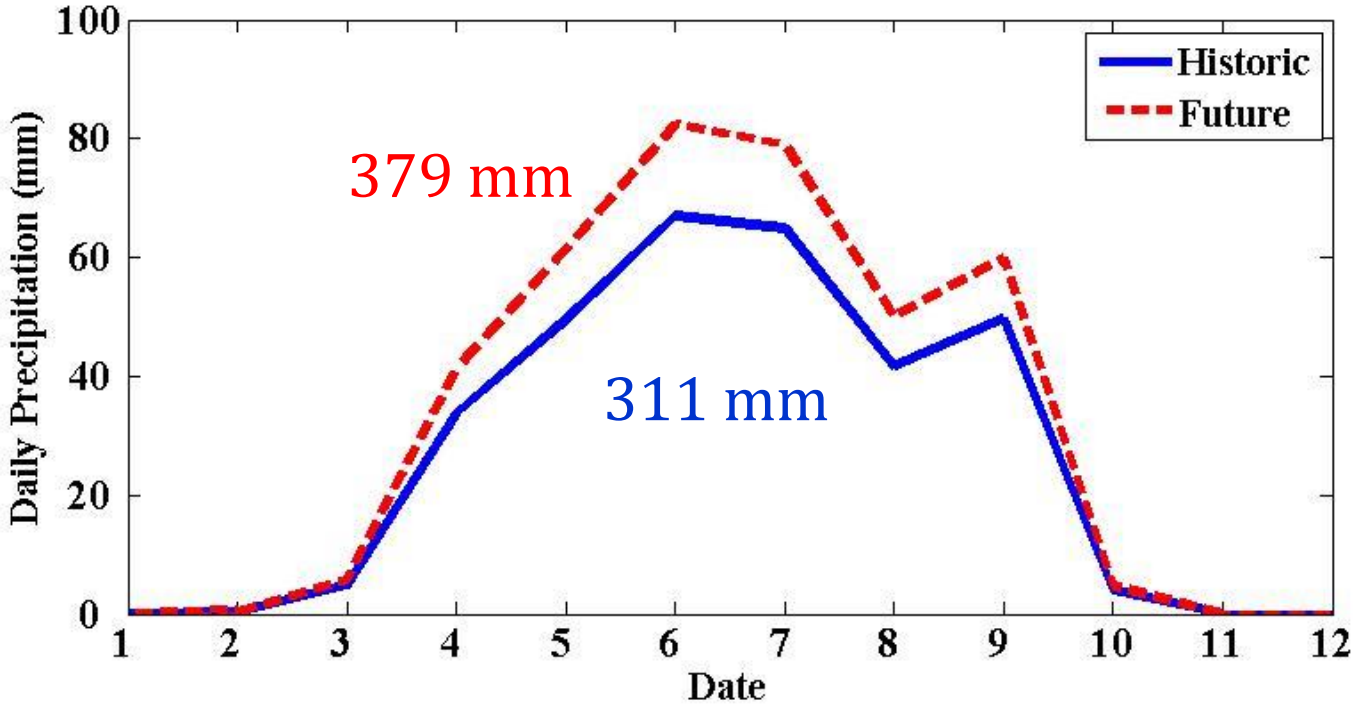
The historical 50-year design storm was estimated based on the historical observations.

The future 50-year design storm was estimated using the bias-corrected climate data from five general circulation models (GCMs) (HadGEM2-ES, GFDL-ESM2M, IPSLCM5A-LR, MIROC-ESM-CHEM, and NorESM1-M) under the RCP8.5 scenario from ISI-MIP.

Results: comparison with historical flood (the August 1963 flood)

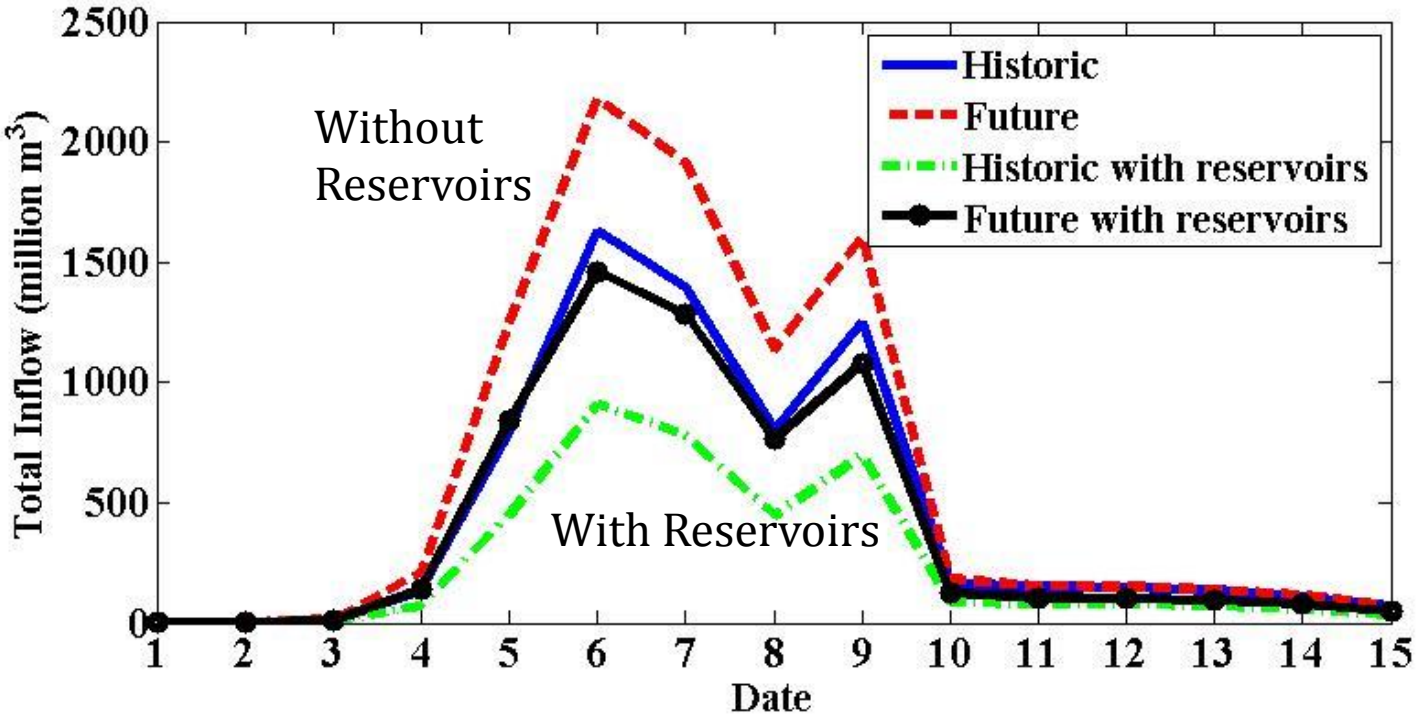
- Observations: The 7-day (August 3-9, 1963) cumulative water volume flowing into the Lake; The water level at some points of the Lake during the 1963 flood event.
- Hydrologic Simulation: The VIC model simulated cumulative runoff matching well with the observations (6 billion m^3) during the flood event, with a relative error less than 0.5%.
- Hydrodynamic Simulation: The model simulated water level agrees with the observed water level during the flood event.

Results: design storm



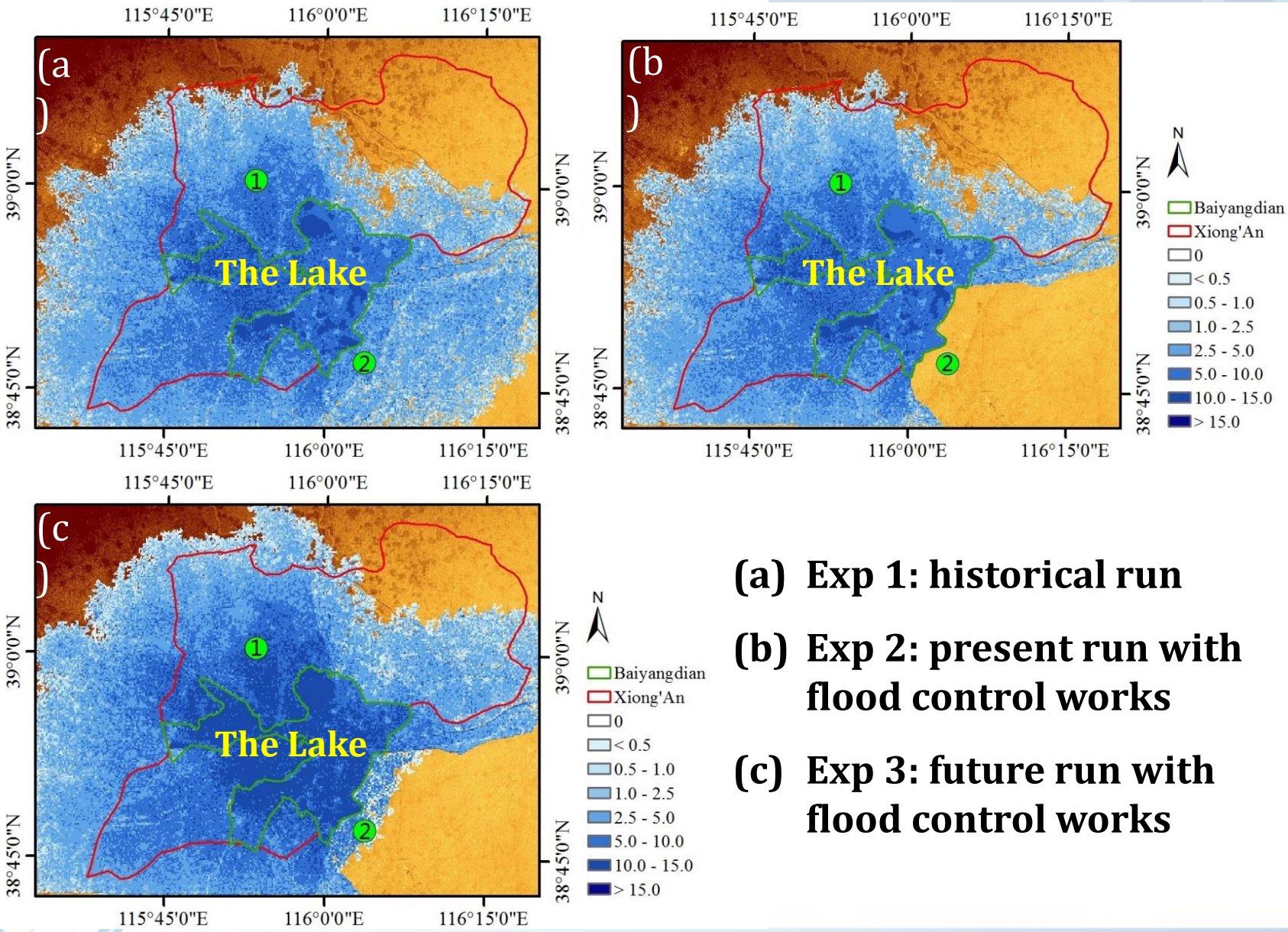
The 50-year design storm for the historical (1952-2010) and future (2032-2090) periods.

Results: design flood



The 50-year design flood into the lake for the historical (1952-2010) and future (2032-2090) periods.

Results: inundation area



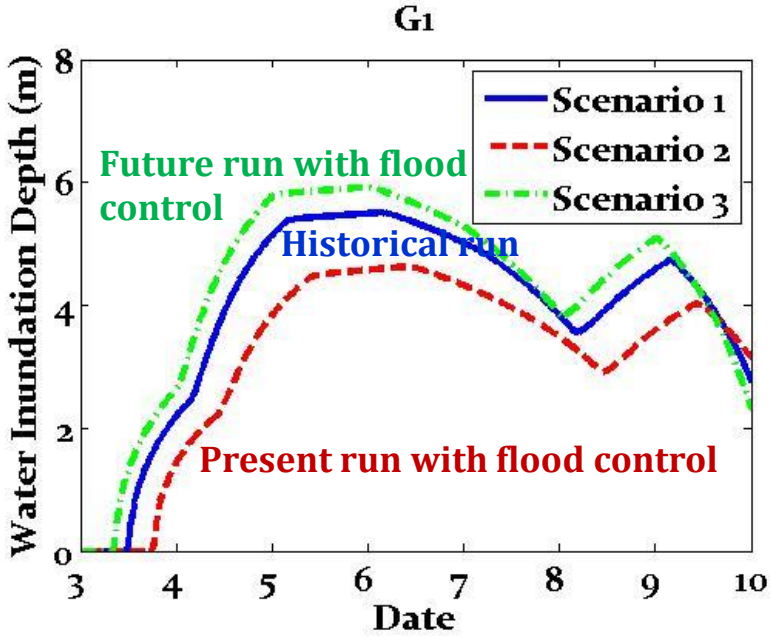
(a) Exp 1: historical run

(b) Exp 2: present run with flood control works

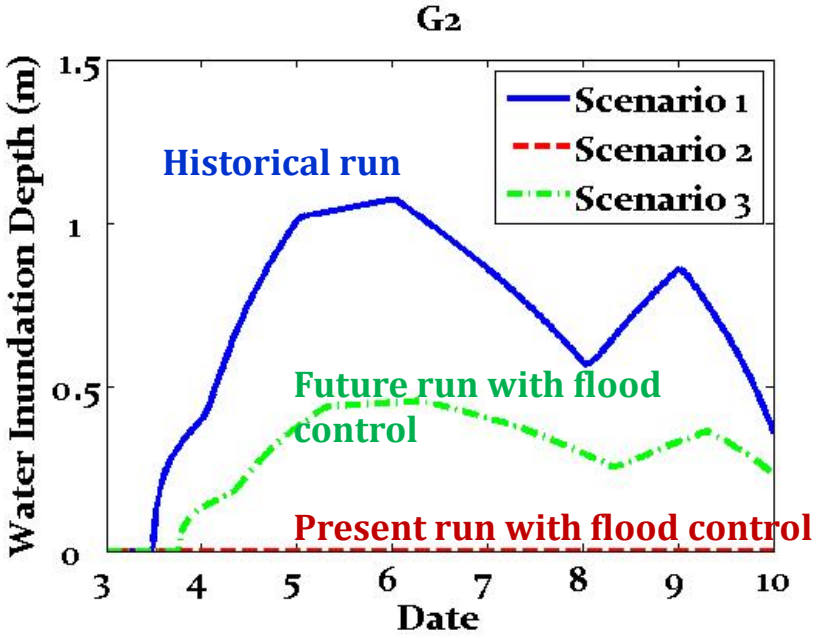
(c) Exp 3: future run with flood control works

Results: inundation depth at the observation points

North Observation Point



Southeast Observation Point



Concluding remarks

- **We have developed a hydrological monitoring and forecast system over China.**
- **The system is promising for drought monitoring and seasonal forecast up to 1-2 months.**
- **In order to get more realistic flood modeling, an integrated approach of hydrologic and hydrodynamic modelling should be implemented, and the effects of flood control works should be taken into accounted in the system.**

Thank you!