Global Change of Hydrology and Flood Risk in a Changing Environment

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Global Change Hydrology: An Emerging Discipline

Water Related Hazards

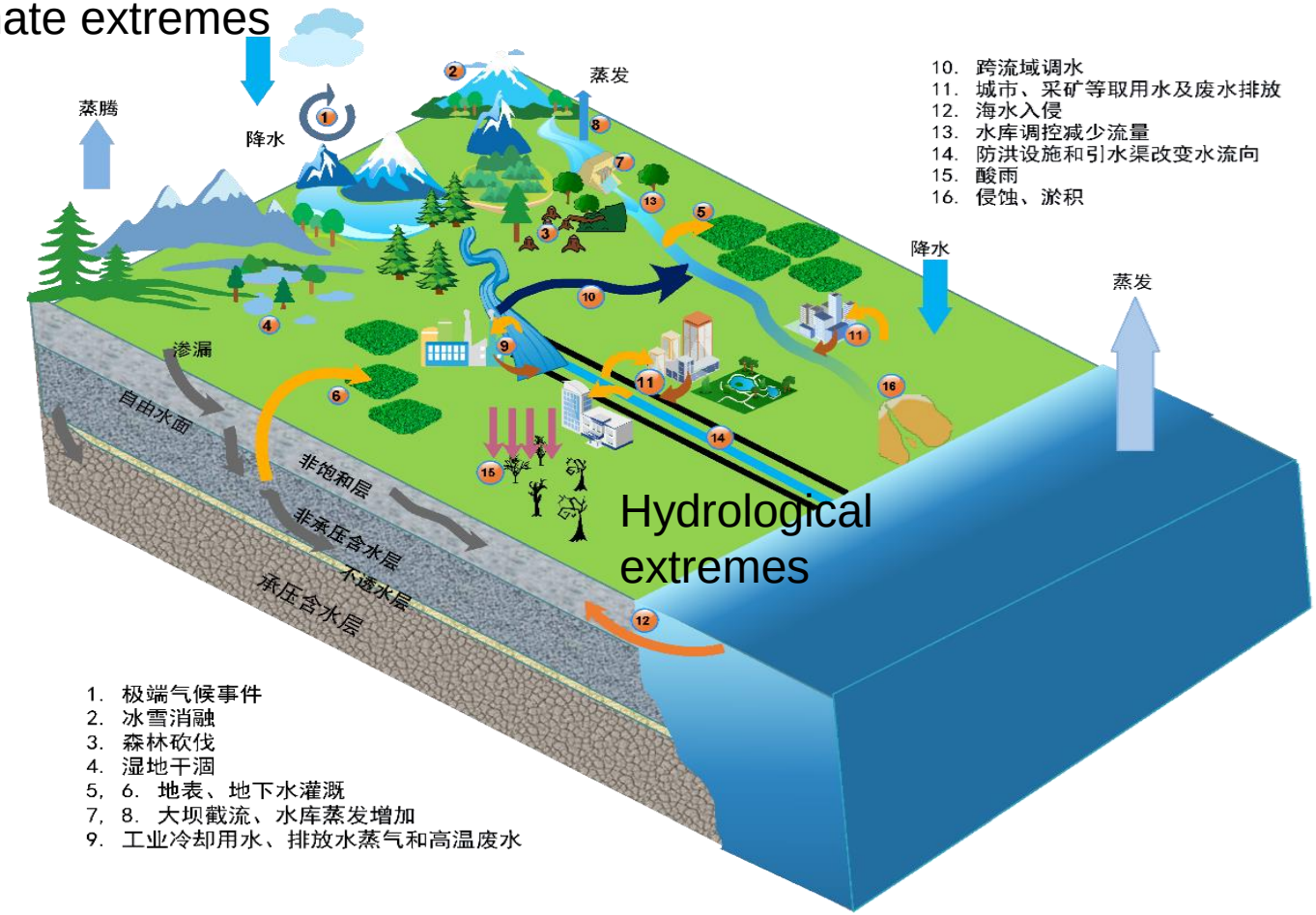
2012/Beijing

Over 90% natural hazards are water related, including drought and flood (United Nations Environment Programme).

Emerging challenges of water related hazard require understanding the global water system and the natural and human-induced factors that influencing the water system.

Global Water System

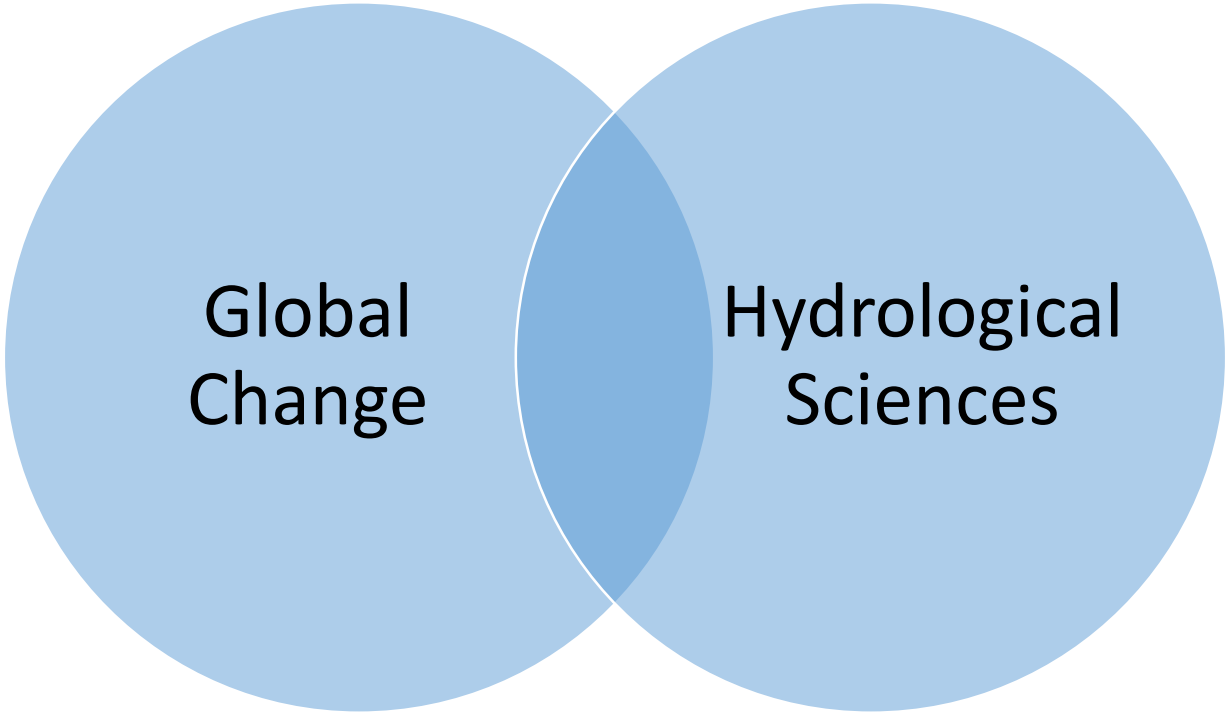
Climate extremes



Hydrological extremes

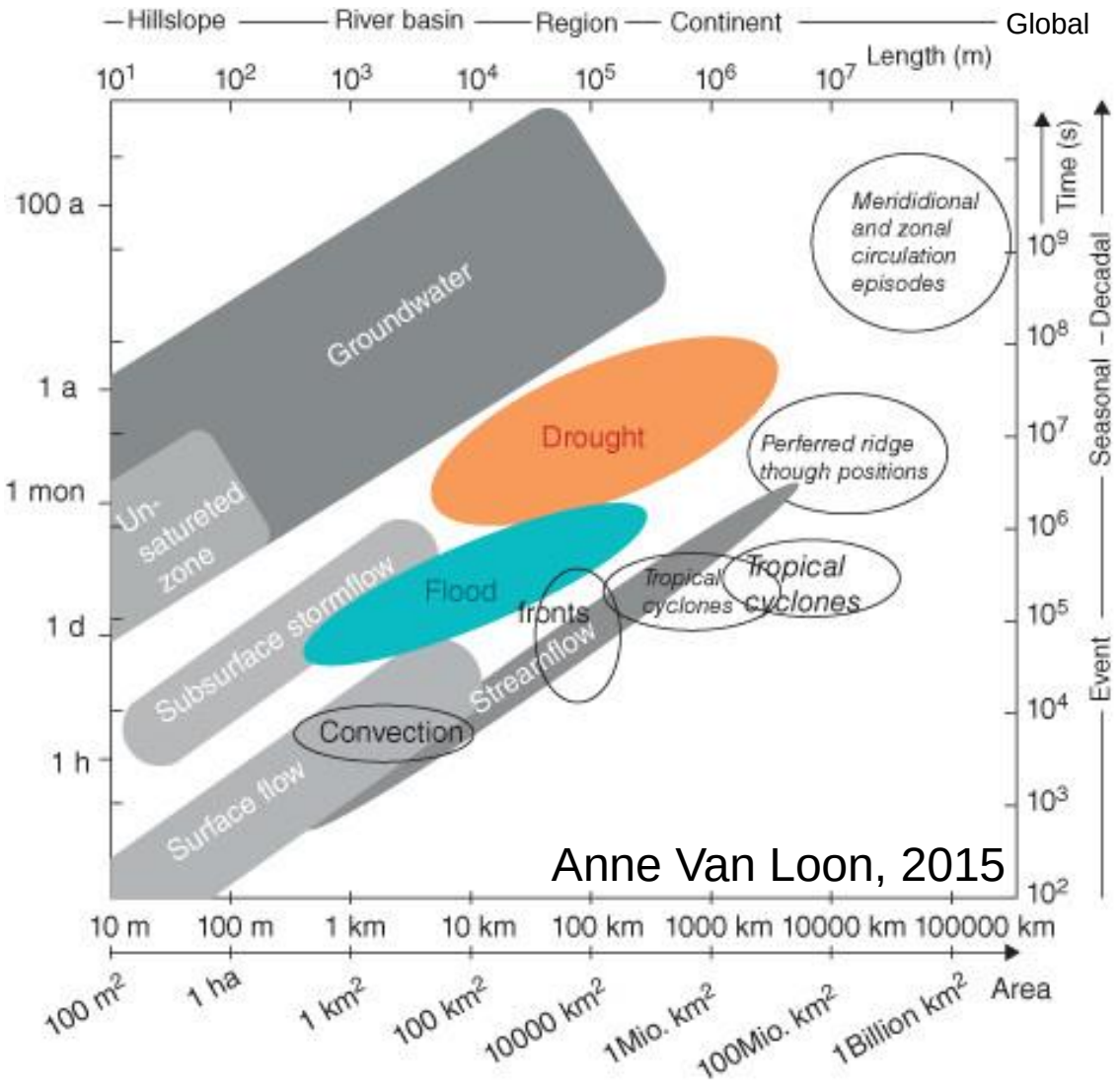
Humanity has become an important driving force of changes to the Earth's hydrosphere and hydro-hazards.

Global Change Hydrology



Global Change Hydrology, an emerging discipline representing an evolution of hydrological sciences towards the linkage with global environmental change for understanding and quantifying the human fingerprint in the global water system.

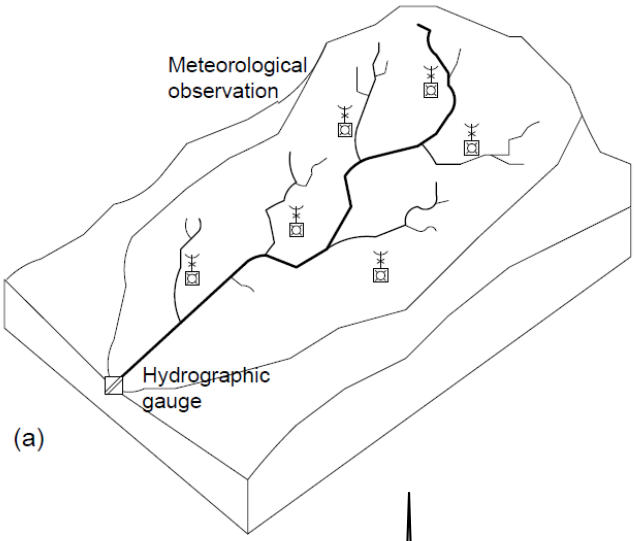
Scales in Hydrology



Global Change Hydrology can be across scales.

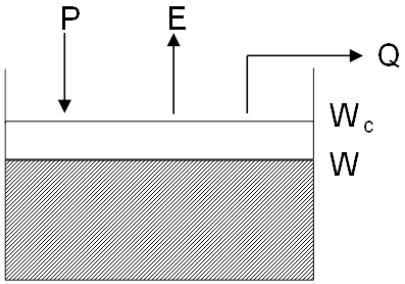
1. How to depict the broad array of human-induced factors in a human-water model?

Hydrological model

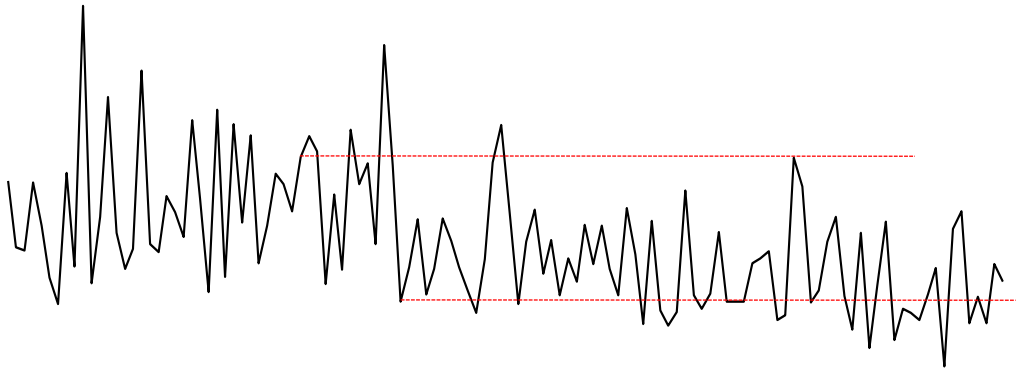


Empirical relationship

Lumped model



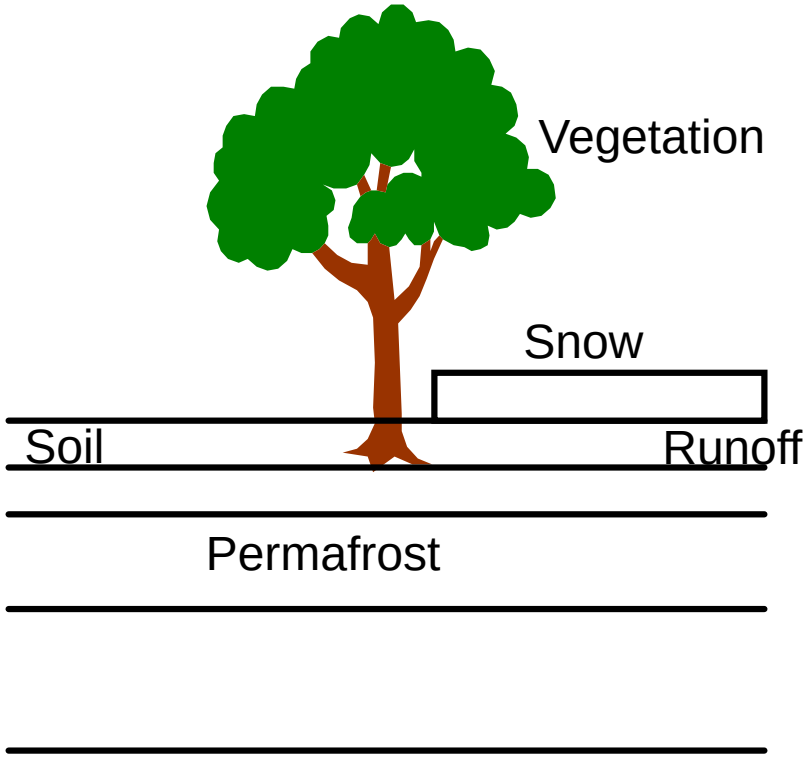
Bucket Model

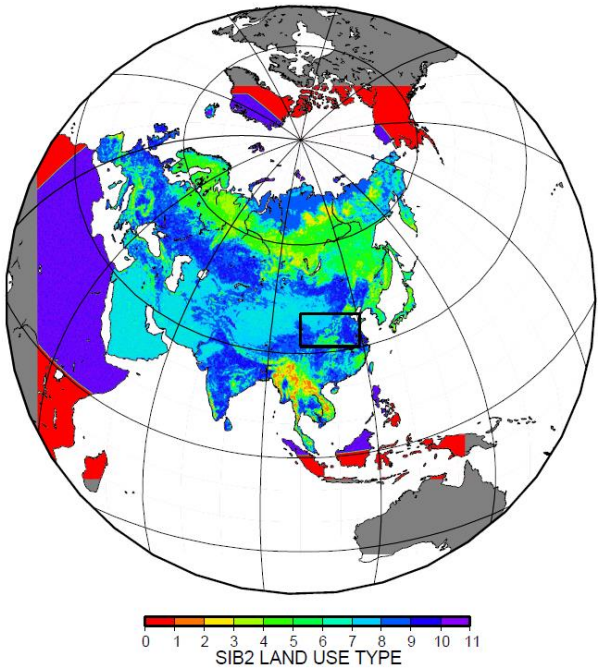


It considers the impact of human-induced climate change.

Tang and Oki, 2016. Terrestrial Water Cycle and Climate Change, AGU Geophysical Monograph

Land Surface Model (LSM)





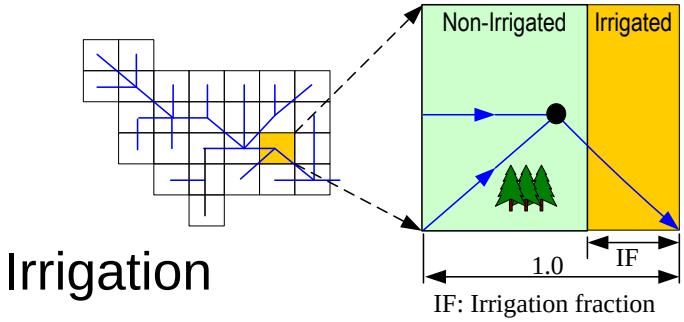
Land cover and land use change

It considers the impact of changes in underlying surface (including vegetation, snow, permafrost)

Tang 2006.

LSM with water management

1) Water demands

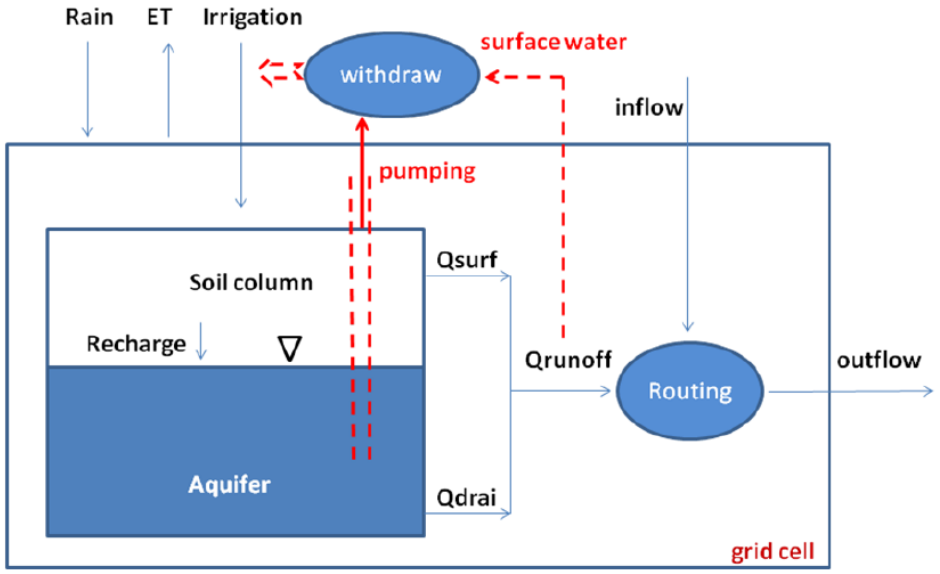


Irrigation

Targeted Soil Moisture Level

Requirement

Wilting Point

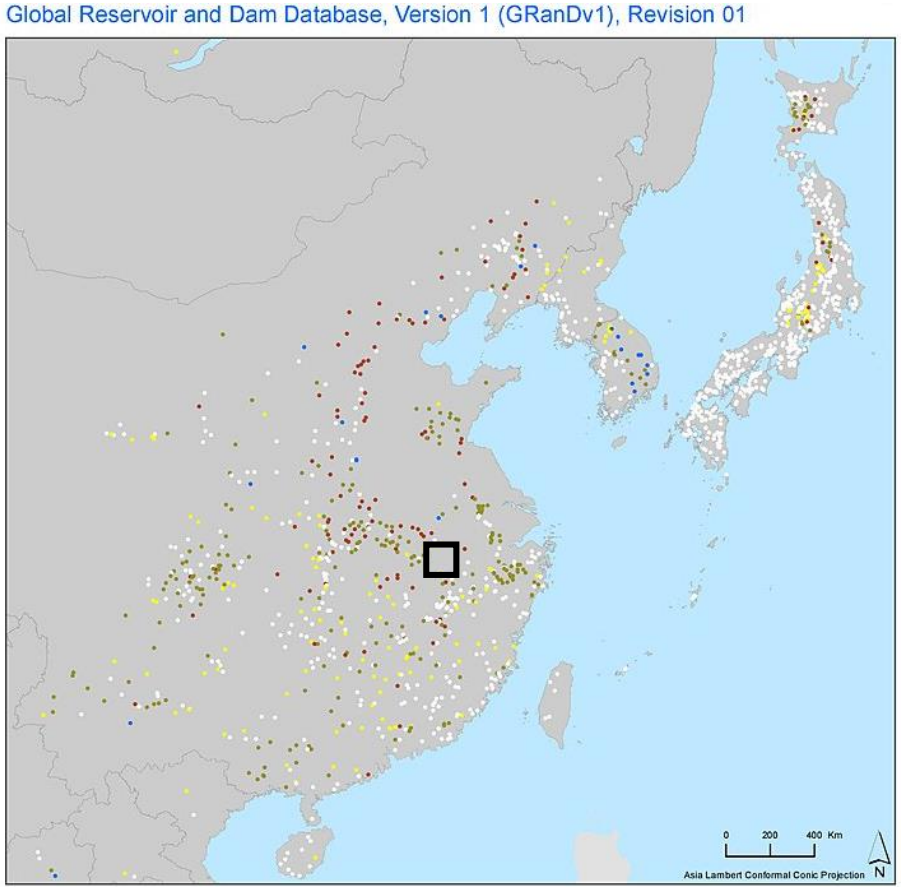


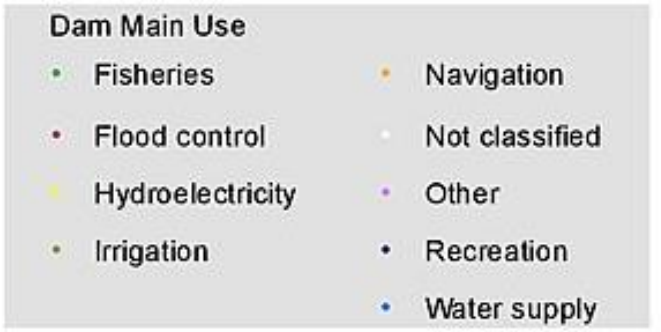
Groundwater withdrawals

Tang, JHM 2007, J Climate 2008; Leng et al. 2014

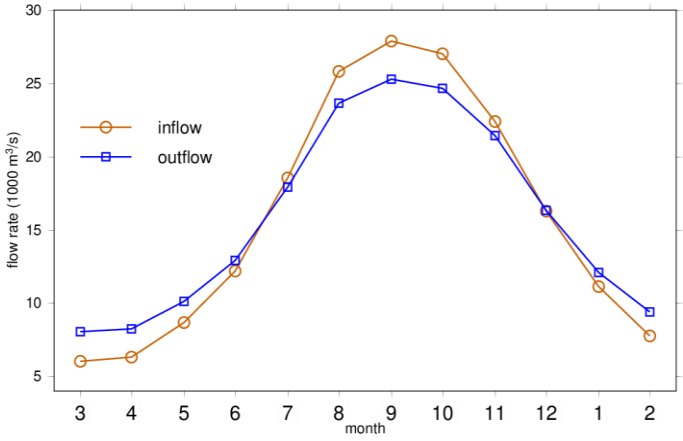
LSM with water management

2) Water supply





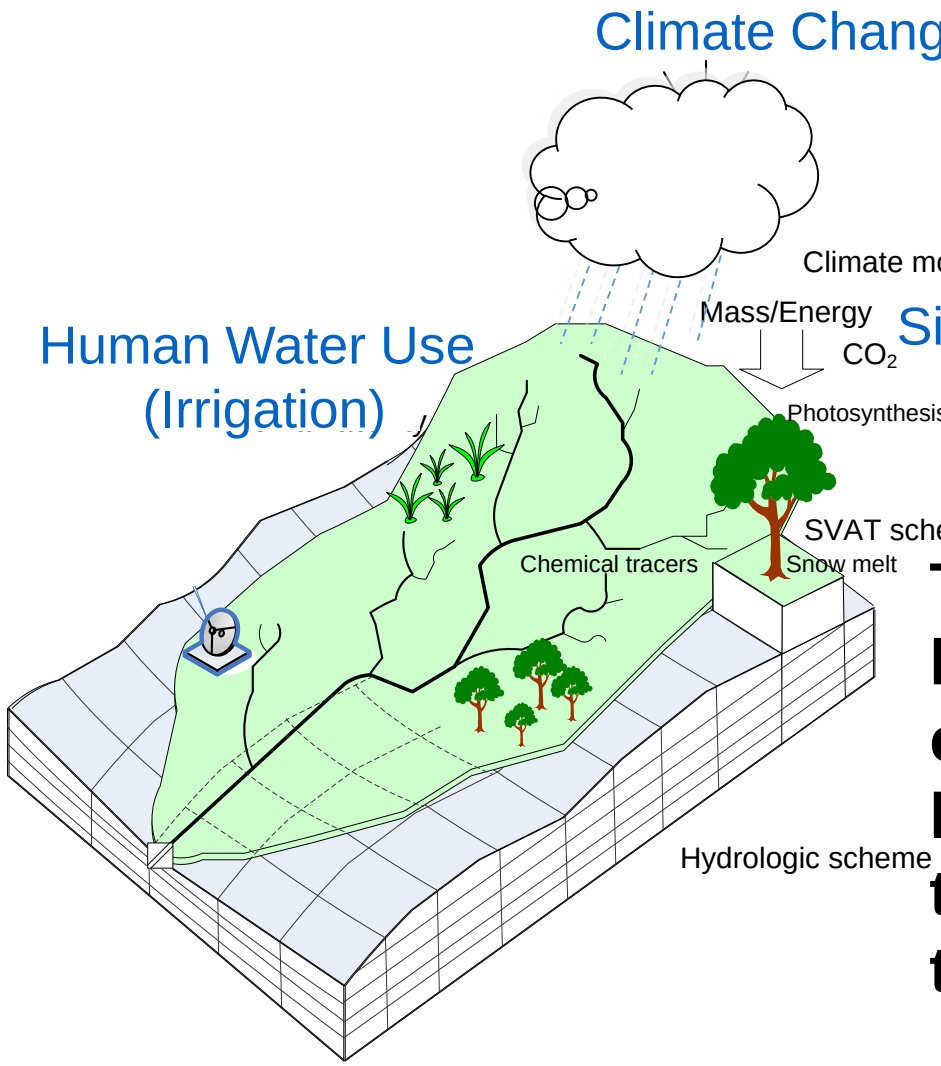
Reservoir model



It considers the impacts of water management.

Liu et al. 2016

The Distributed Biosphere-Hydrological (DBH) model

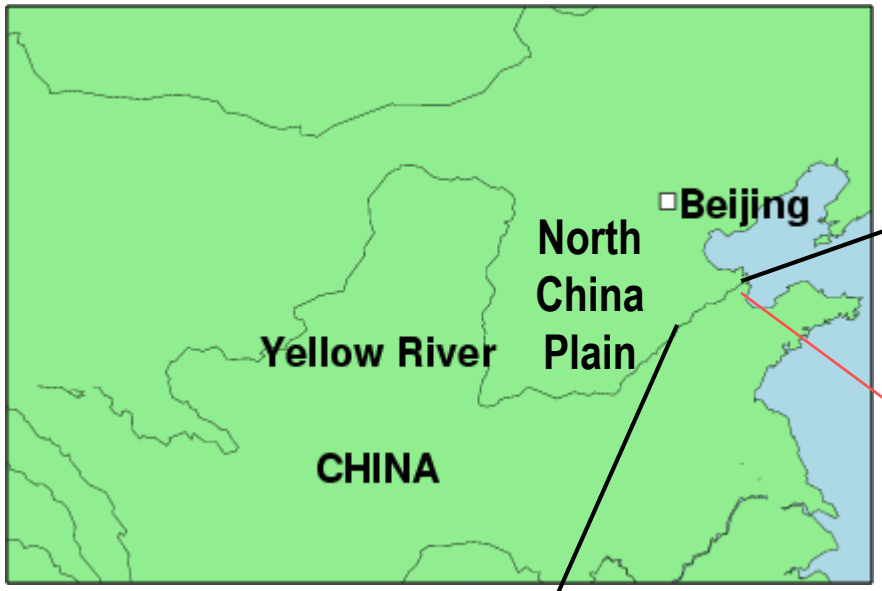


The model is a coupled human-water model that can represent most major human-induced factors that influencing the terrestrial water cycle.

Tang et al. JHM 2007.

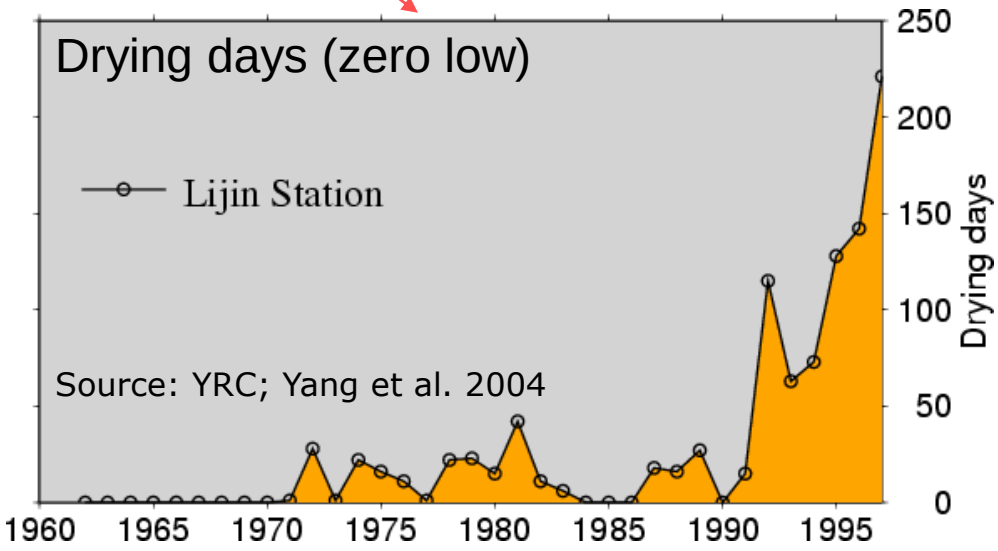
2. How to separate human and climate impacts on the hydrological cycle?

Yellow River run dry in the 1990s



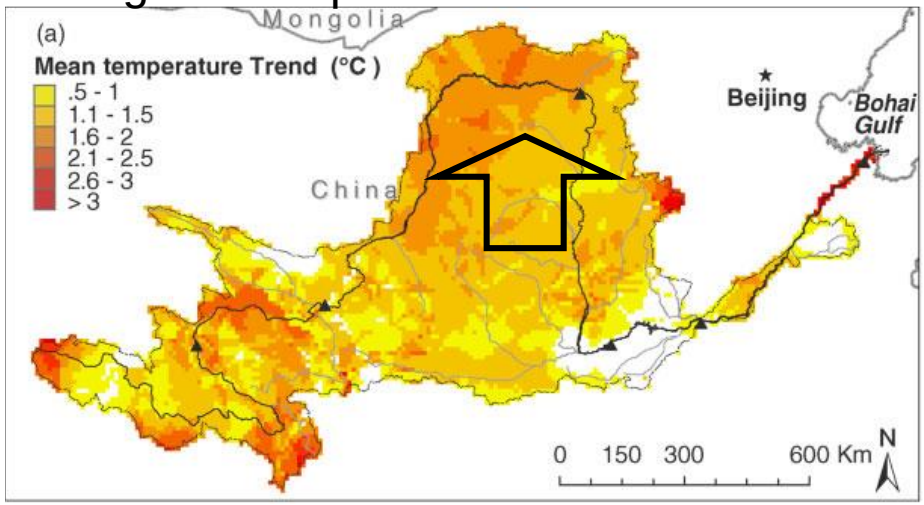
Red -crowned Crane

Huang et al. 2009

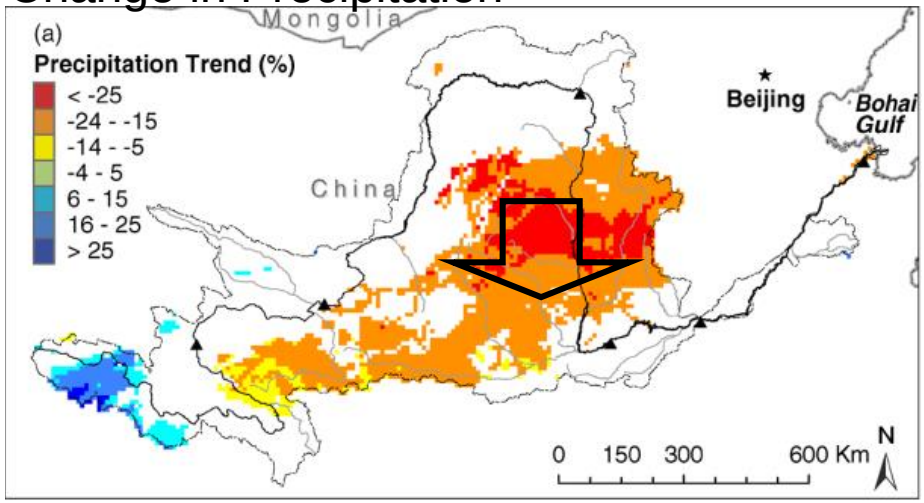


What factors contribute to the drying?

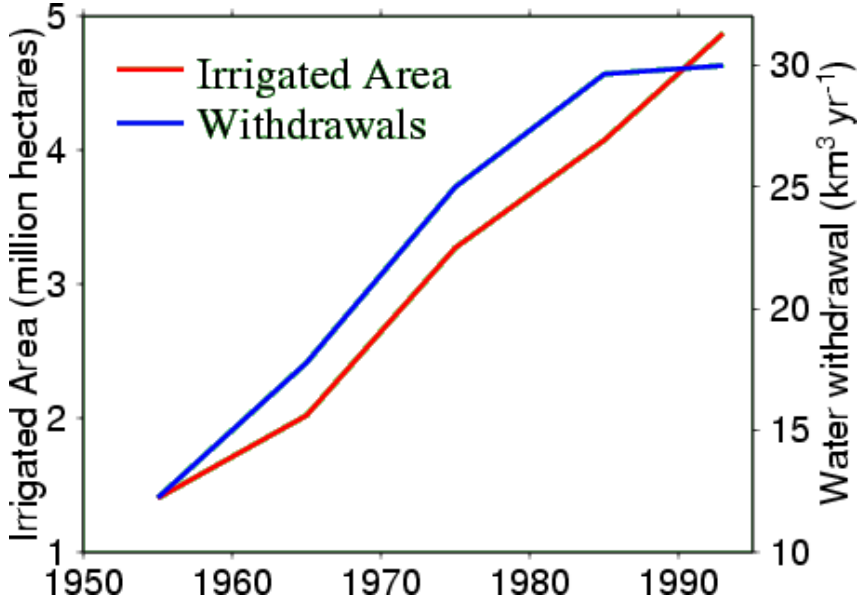
Change in Temperature



Change in Precipitation



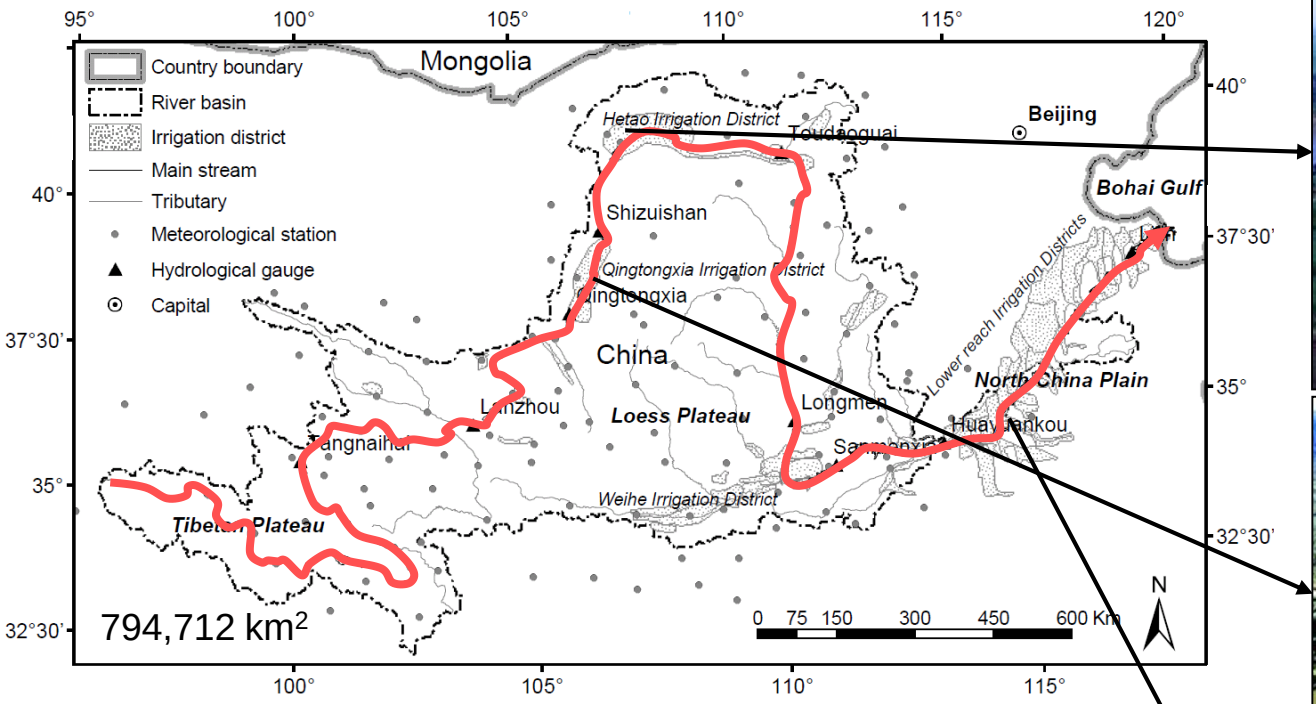
Source: Tang et al. 2008

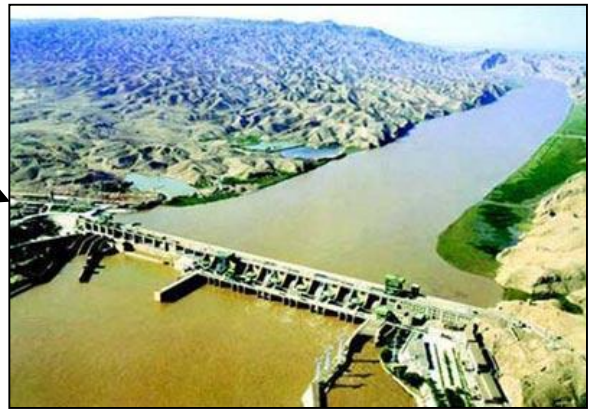


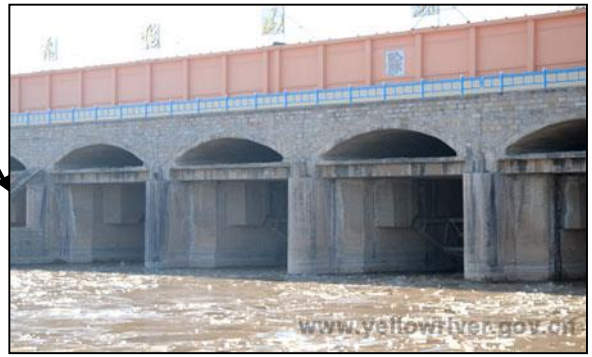
Candidate Factors

- Climatic Changes
- Water withdrawals
- Vegetation changes

Model settings



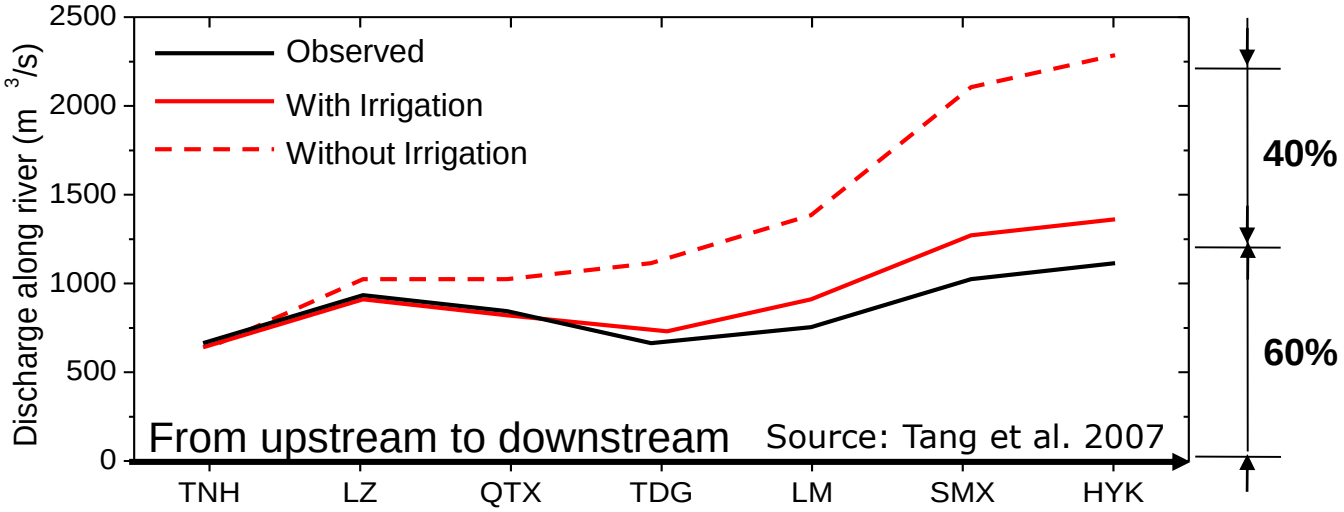




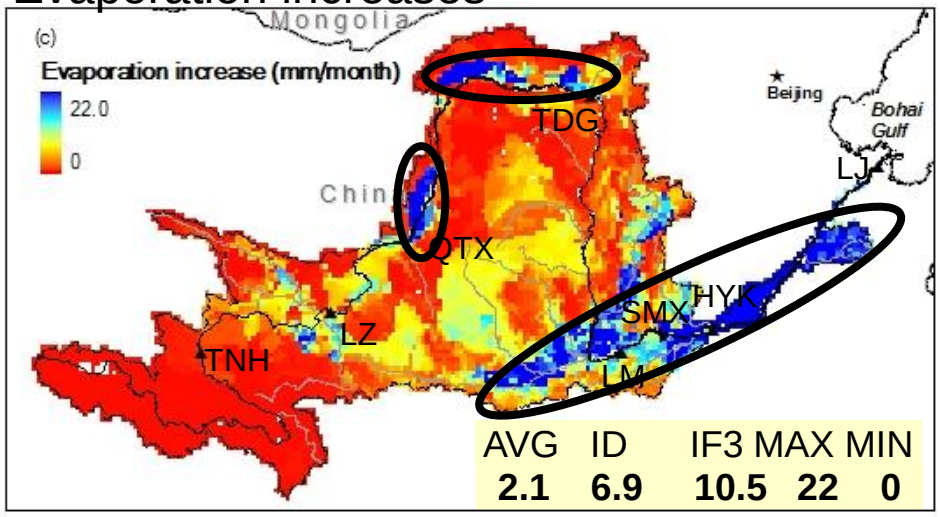
DBH enables direct comparisons with the managed flow, rather than the 'naturalized' flow.

Photo credit: Sina, Hudong wiki, Yellowriver.gov.cn

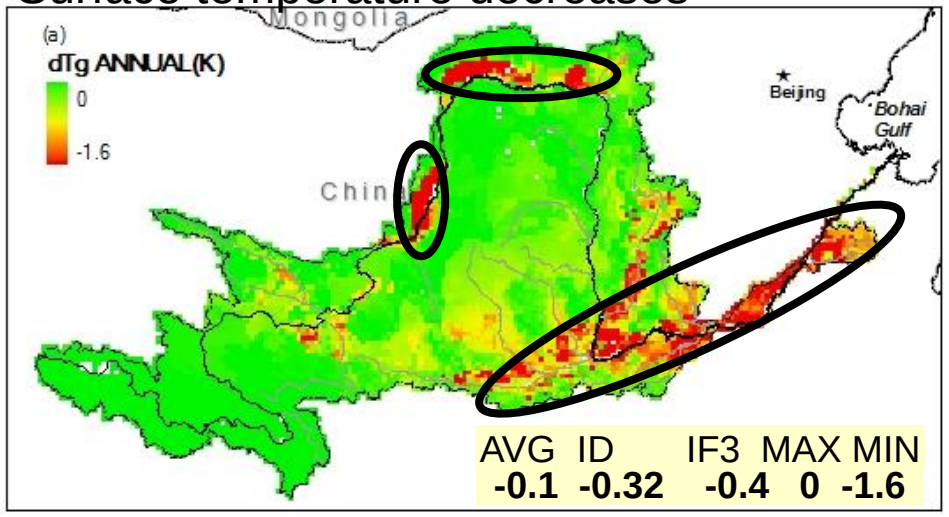
Effects of irrigation



Evaporation increases

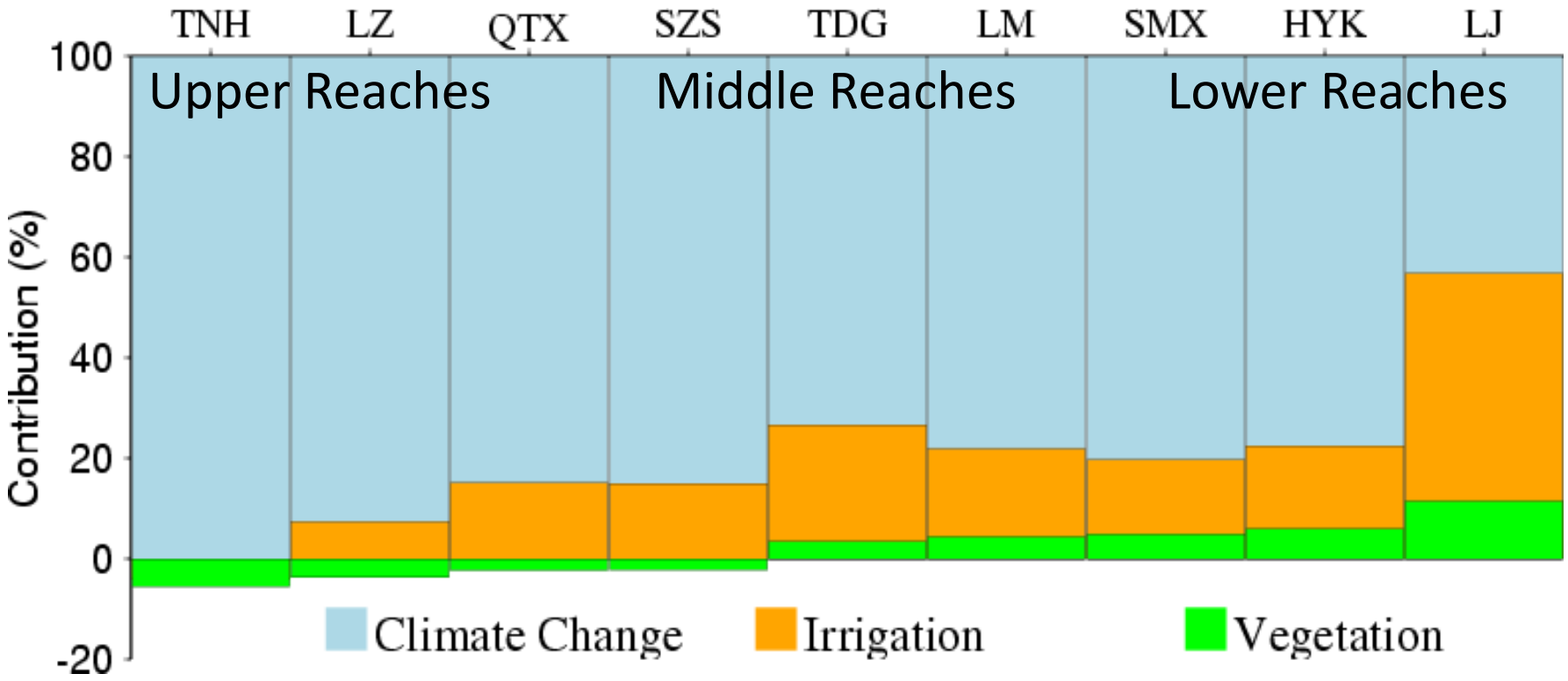


Surface temperature decreases



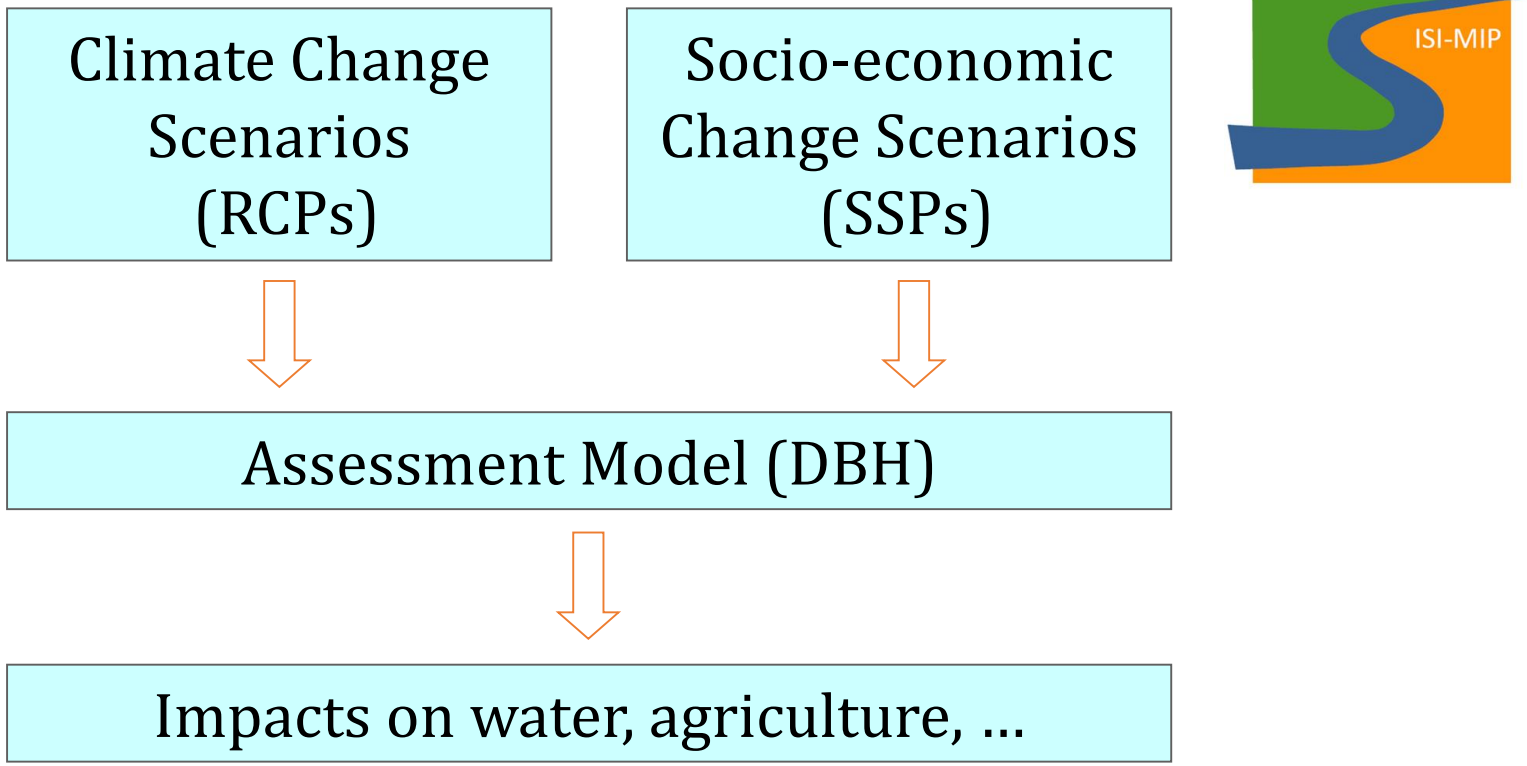
Averaged (AVG) **In Irrigation Districts (ID)** **Irrigated Fraction>0.3(IF3)** **MAXimum** **MINimum**

Major drivers contributing to the drying

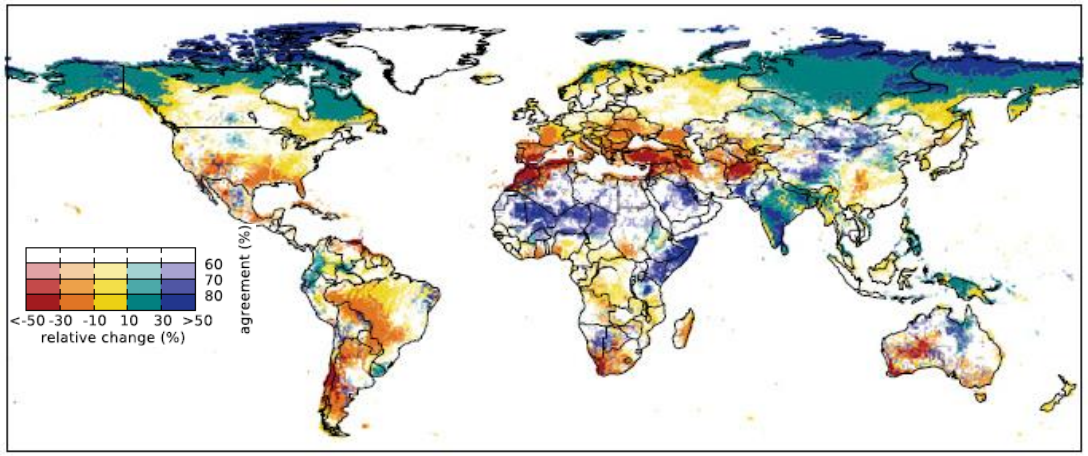


3. How to assess water-related risks and build resilience?

Climate change impact assessment

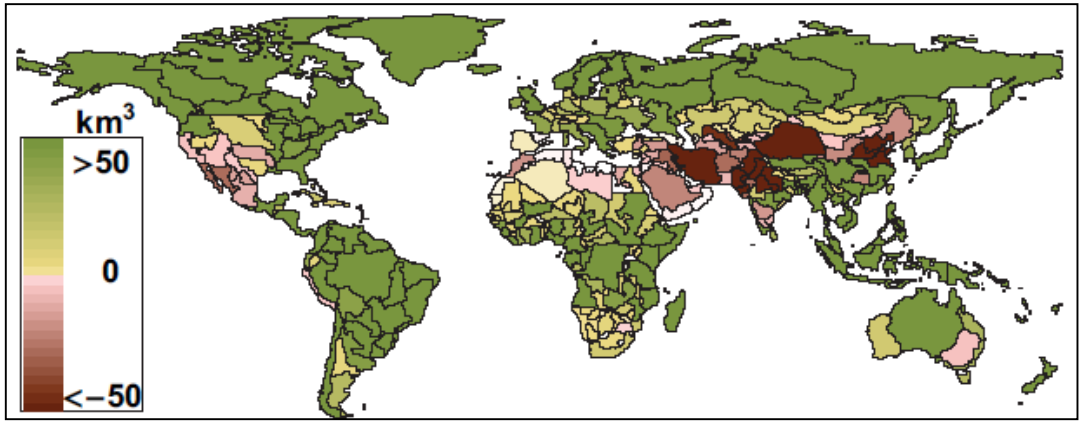


Climate Change Impacts



Schewe et al. PNAS 2014

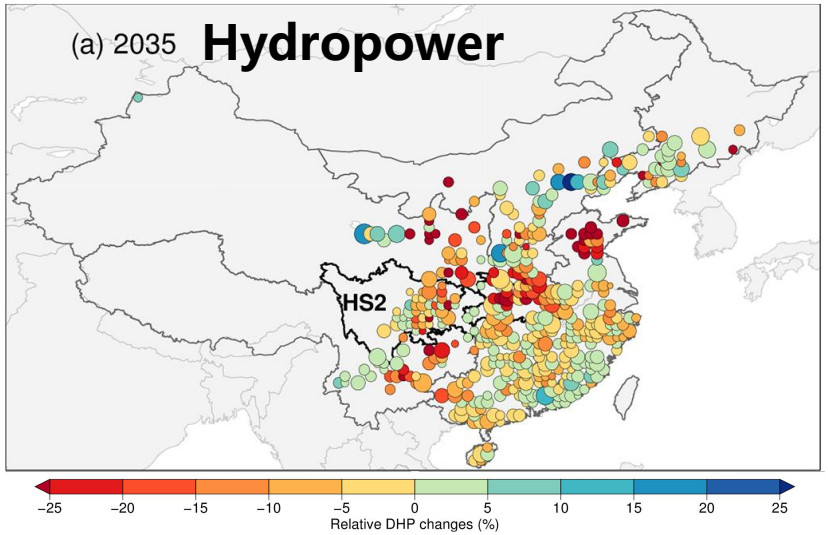
Relative change in annual discharge at 2 °C compared with present day, under RCP8.5.

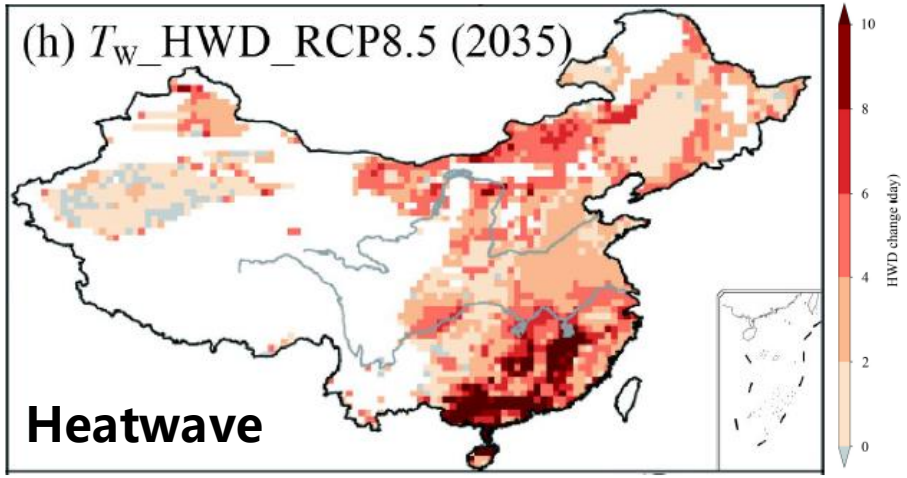


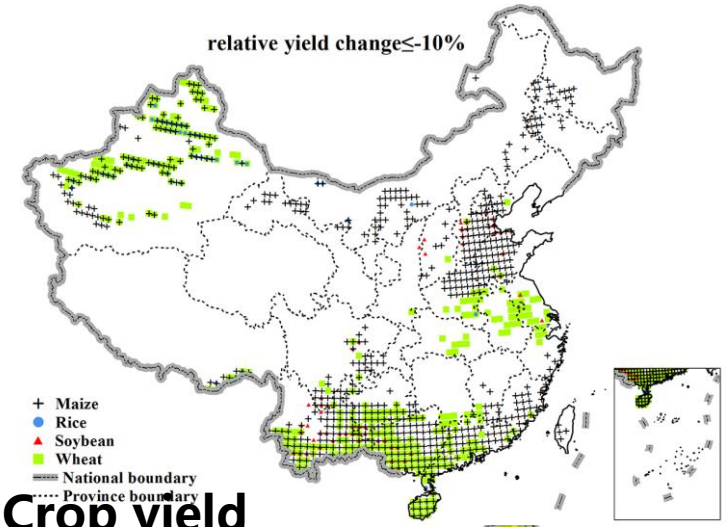
Elliott et al. PNAS 2014

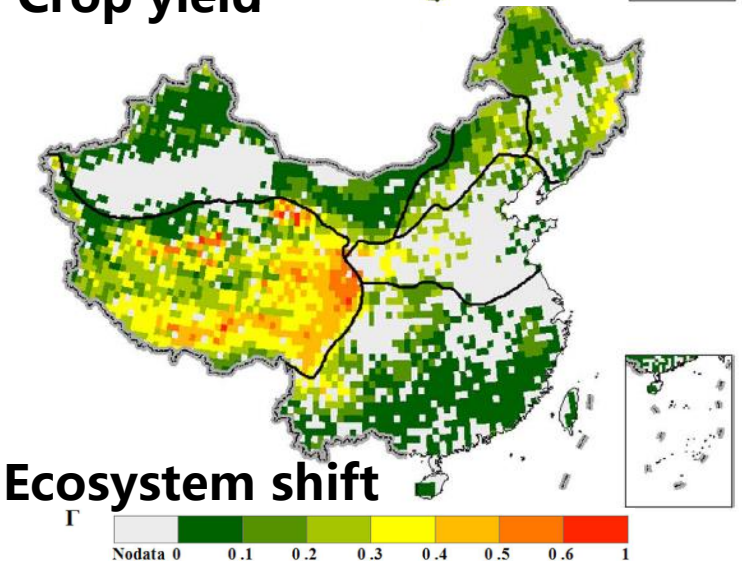
Median potential end-of-century renewable water abundance/deficiency in average cubic kilometers per year under RCP 8.5

Risks at different sectors





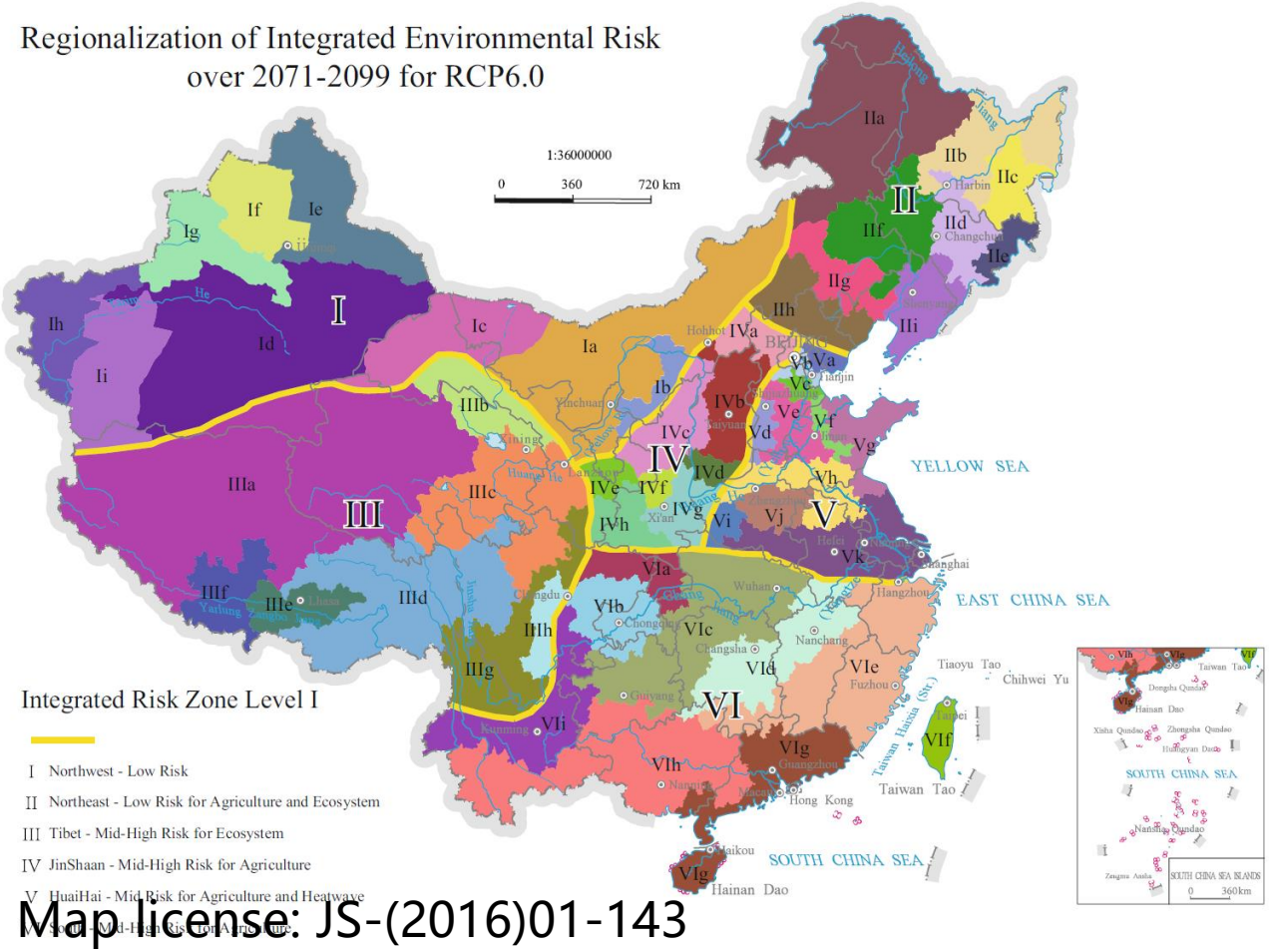




Identified areas with high risk.

Liu et al.; Yin et al.

Risk atlas under climate change



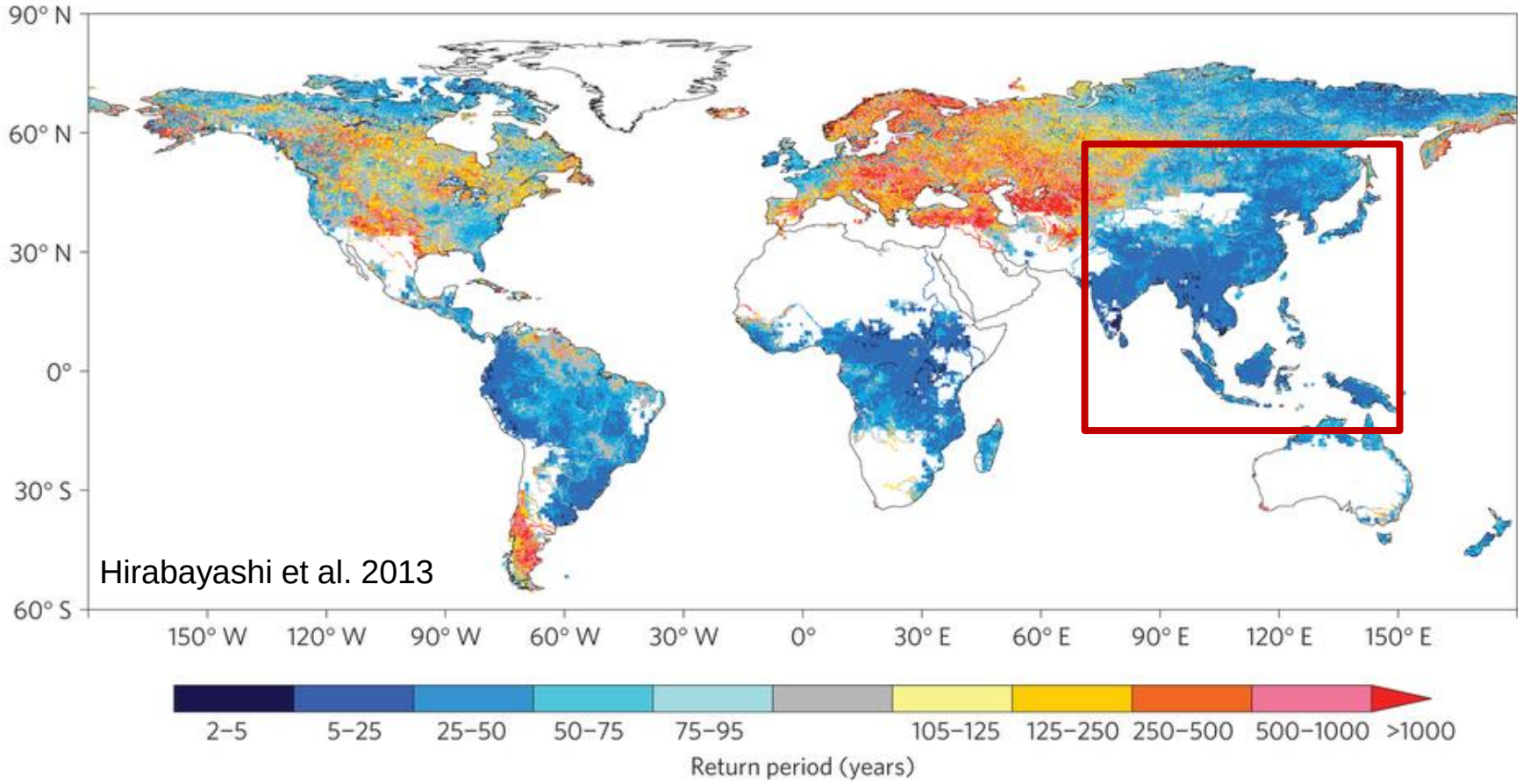
Map license: JS-(2016)01-143

With the risk atlas, scientific knowledge can be translated to policy and management practices.

Tang & Ge (Eds) 2018

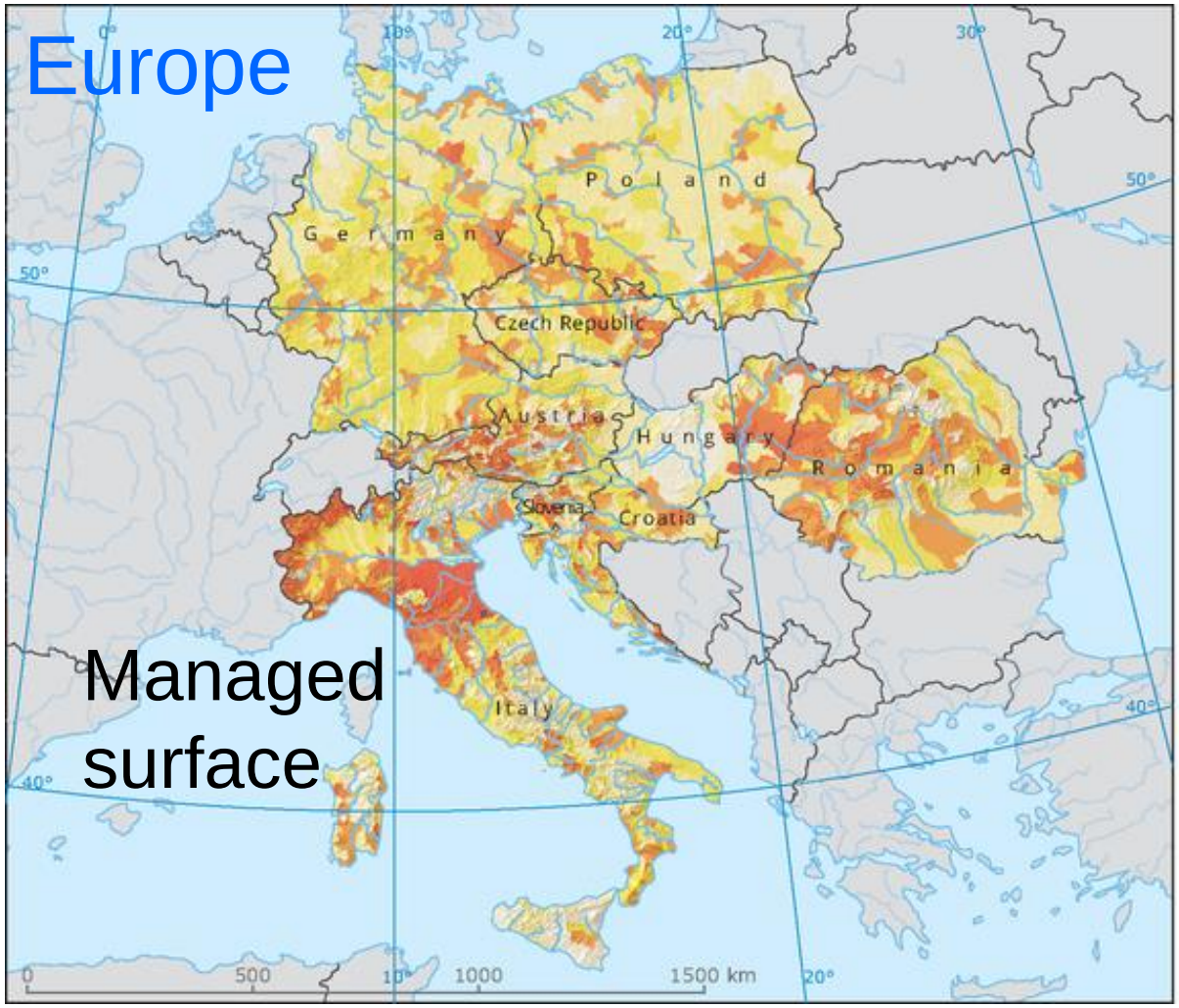
Flood Risk in a Changing Environment

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.

A large portion of people lives in flood-prone area



Share of population living in the floodplain areas

Percentage

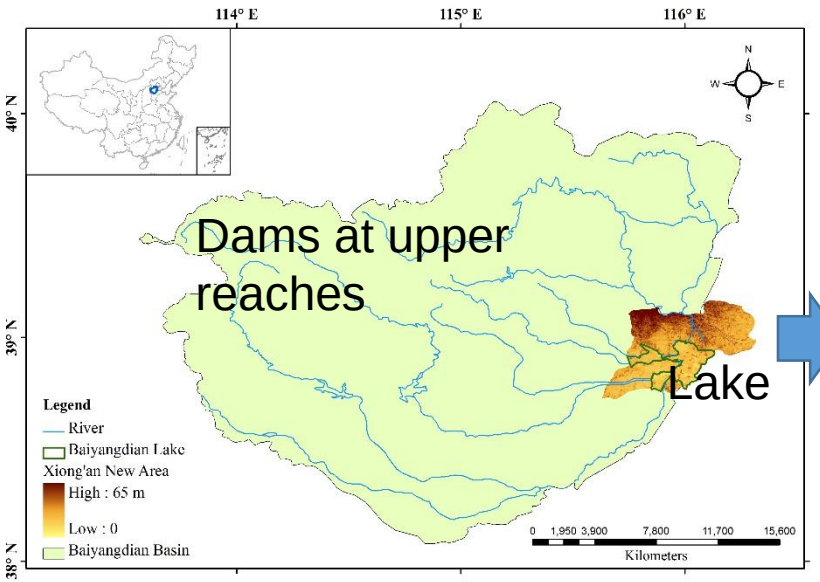
- 0
- 0–2
- 2–5
- 5–10
- 10–25
- 25–50
- 50–100
- Outside coverage

Note

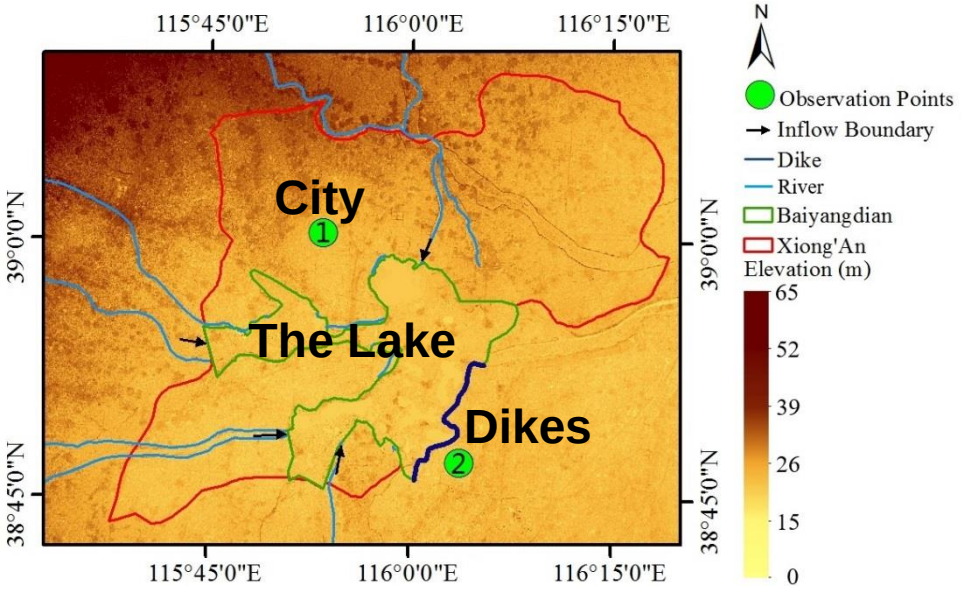
Based on the EU Floods Directive Flood Hazard Mapping, medium scenario

European Environment Agency

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

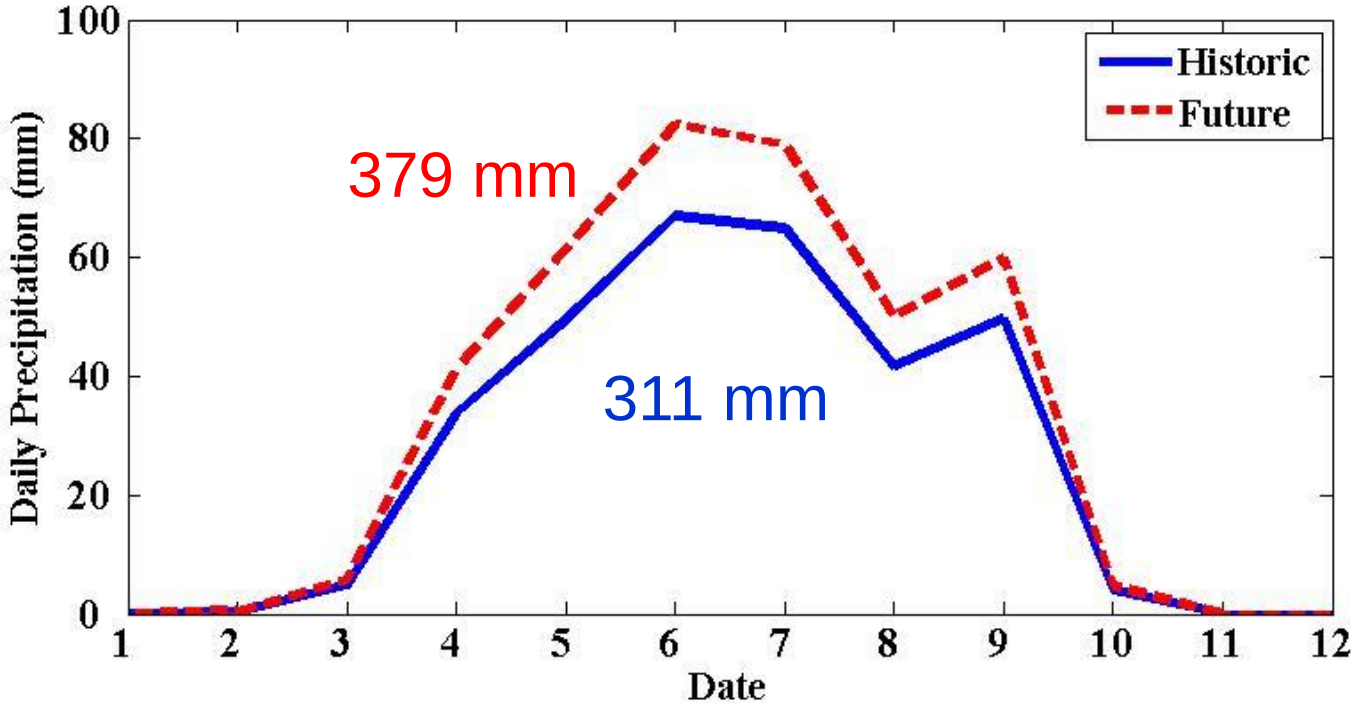
- **Exp 1: Flood risk of a historical 50-year flood (the August 1963 flood)**
- **Exp 2: Present flood risk, using the same historical 50-year flood with the flood control works**
- **Exp 3: A future 50-year flood with the heightened dike and reservoirs**

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.

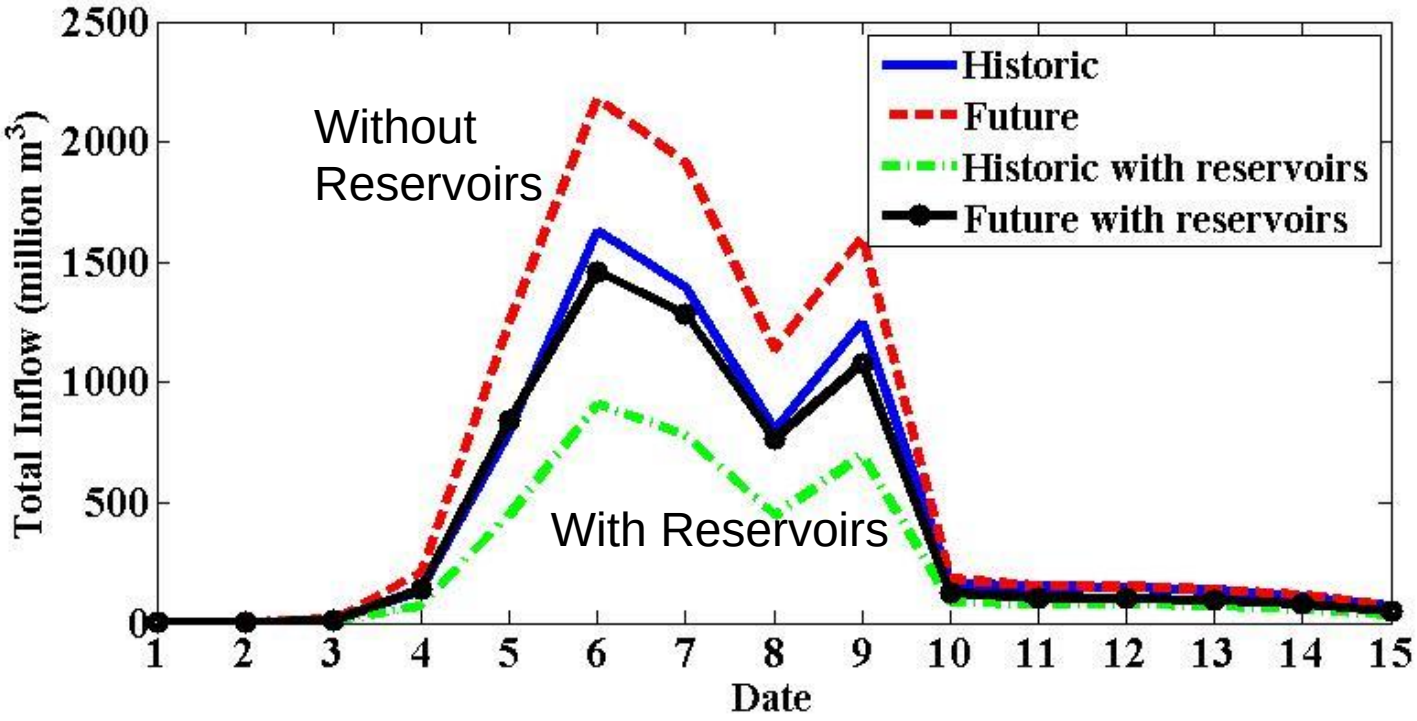
Wang et al. HSJ 2019 accepted

50-year storms



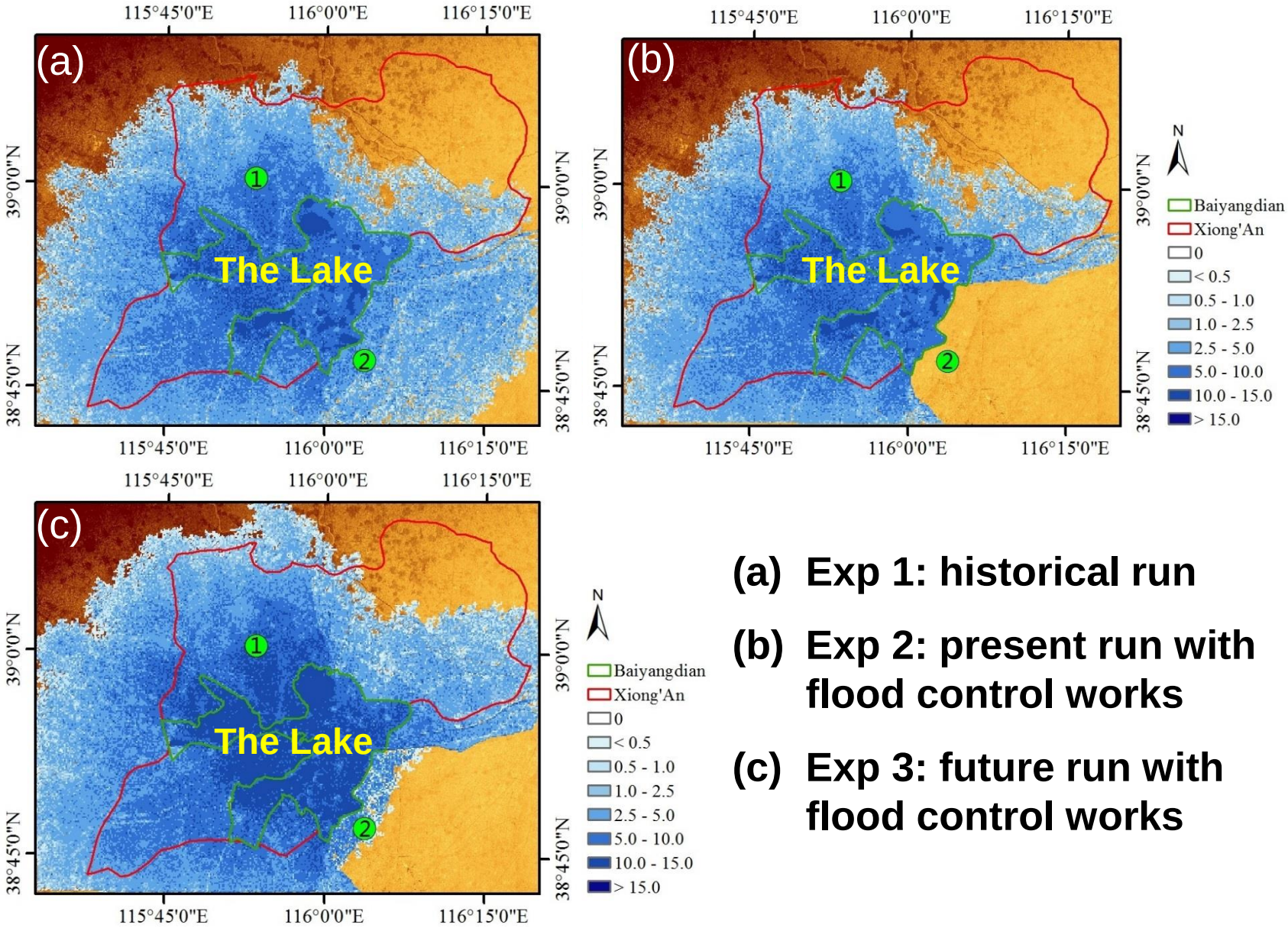
The 50-year design storm for the historical (1952-2010) and future (2032-2090) periods.

50-year floods



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

Results: inundation area



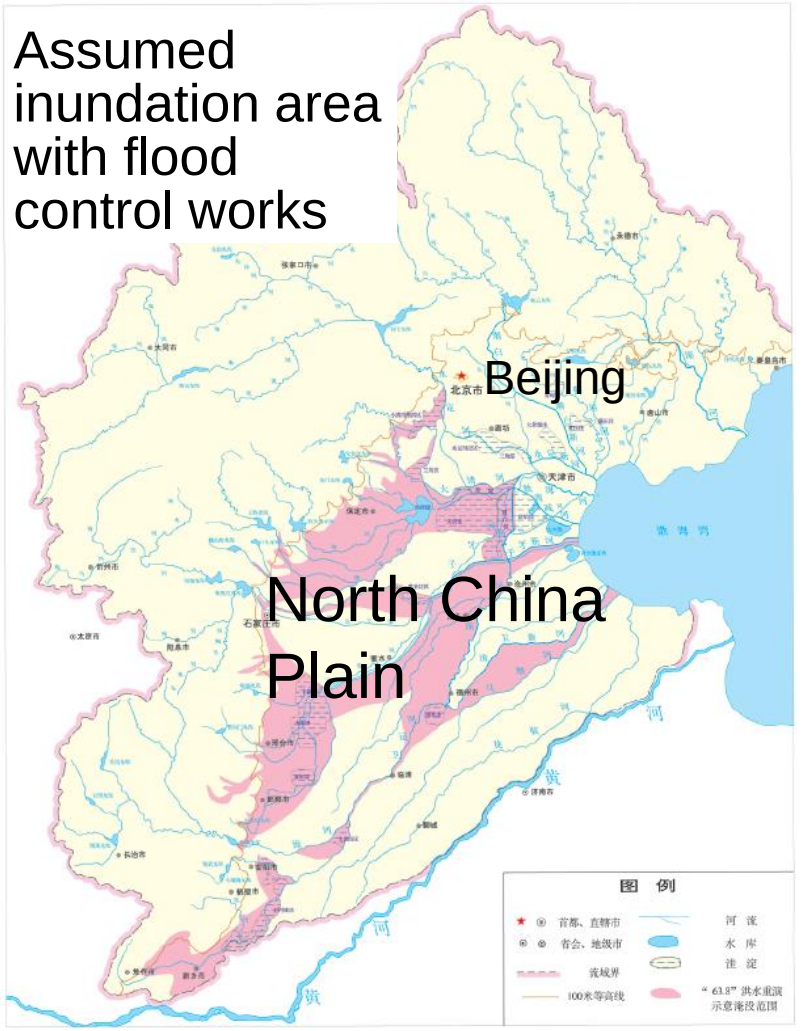
(a) Exp 1: historical run

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

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

Wang et al. HSJ 2019 accepted

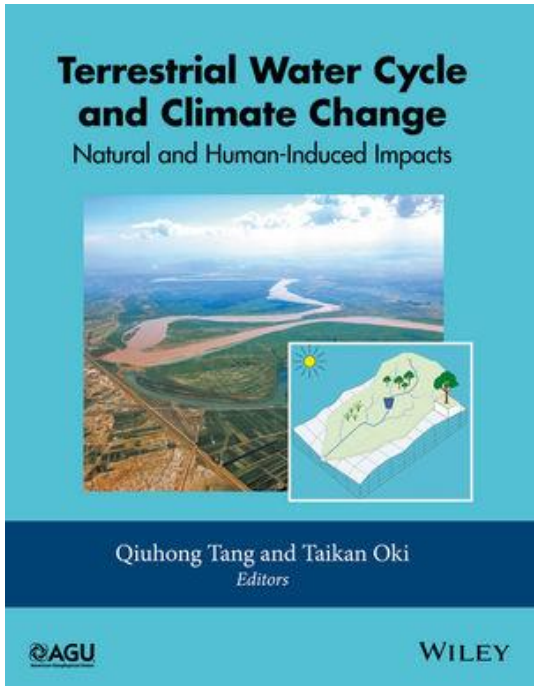
Flood risk with flood control measures at Haihe River Basin, August 1963 flood

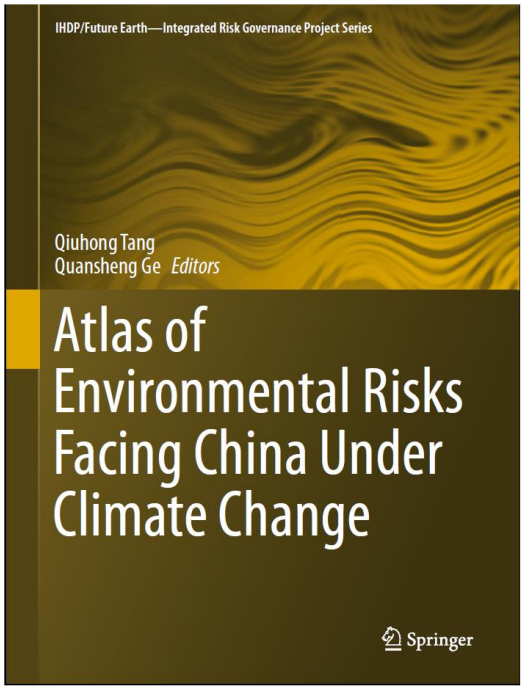


Take home message

- **A new discipline of Global Change Hydrology emerges.**
- **Understanding human-induced impacts to the global water system is the key mission of Global Change Hydrology**
- **Considerable advances have been made in the past, but more efforts and collaborations are required in order to understand the risks under changing environment and to shape the future of Global Change Hydrology.**

Thank you





http://hydro.igsnrr.ac.cn