Global Change of Hydrology and Flood Risk in a Changing Environment

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Global Change Hydrology:
An Emerging Discipline
Water Related Hazards

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

Anne Van Loon, 2015
1. How to depict the broad array of human-induced factors in a human-water model?
It considers the impact of human-induced climate change.

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

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.

2. How to separate human and climate impacts on the hydrological cycle?
Yellow River run dry in the 1990s

Source: YRC; Yang et al. 2004

Huang et al. 2009

Red-crowned Crane

Drying days (zero low)

Lijin Station

Source: YRC; Yang et al. 2004
What factors contribute to the drying?

**Change in Temperature**

- Mean temperature Trend (°C)
  - >3
  - 2.5 - 3
  - 2 - 2.5
  - 1.6 - 2
  - 1.1 - 1.5
  - 0.5 - 1

**Change in Precipitation**

- Precipitation Trend (%)
  - >25
  - 16 - 25
  - 6 - 15
  - 4 - 5
  - -4 - -5
  - -24 - -15
  - < -25

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**Candidate Factors**

- Climatic Changes
- Water withdrawals
- Vegetation changes

Source: Tang et al. 2008
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
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Source: Tang et al. 2007
Major drivers contributing to the drying

- Upper Reaches
- Middle Reaches
- Lower Reaches

Contributions:
- Climate Change
- Irrigation
- Vegetation
3. How to assess water-related risks and build resilience?
Climate change impact assessment

Climate Change Scenarios (RCPs)

Socio-economic Change Scenarios (SSPs)

Assessment Model (DBH)

Impacts on water, agriculture, ...
Climate Change Impacts

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

Schewe et al. PNAS 2014

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

Elliott et al. PNAS 2014
Risks at different sectors

Identified areas with high risk.

Liu et al.; Yin et al.
With the risk atlas, scientific knowledge can be translated to policy and management practices.
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.

Europe

Managed surface

European Environment Agency
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

Actual inundation area

Assumed inundation area with flood control works

North China Plain
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