Impacts of Different Human Activities on Hydrological Drought in Huai River based on PCR-GLOBWB model

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Content

1 Background

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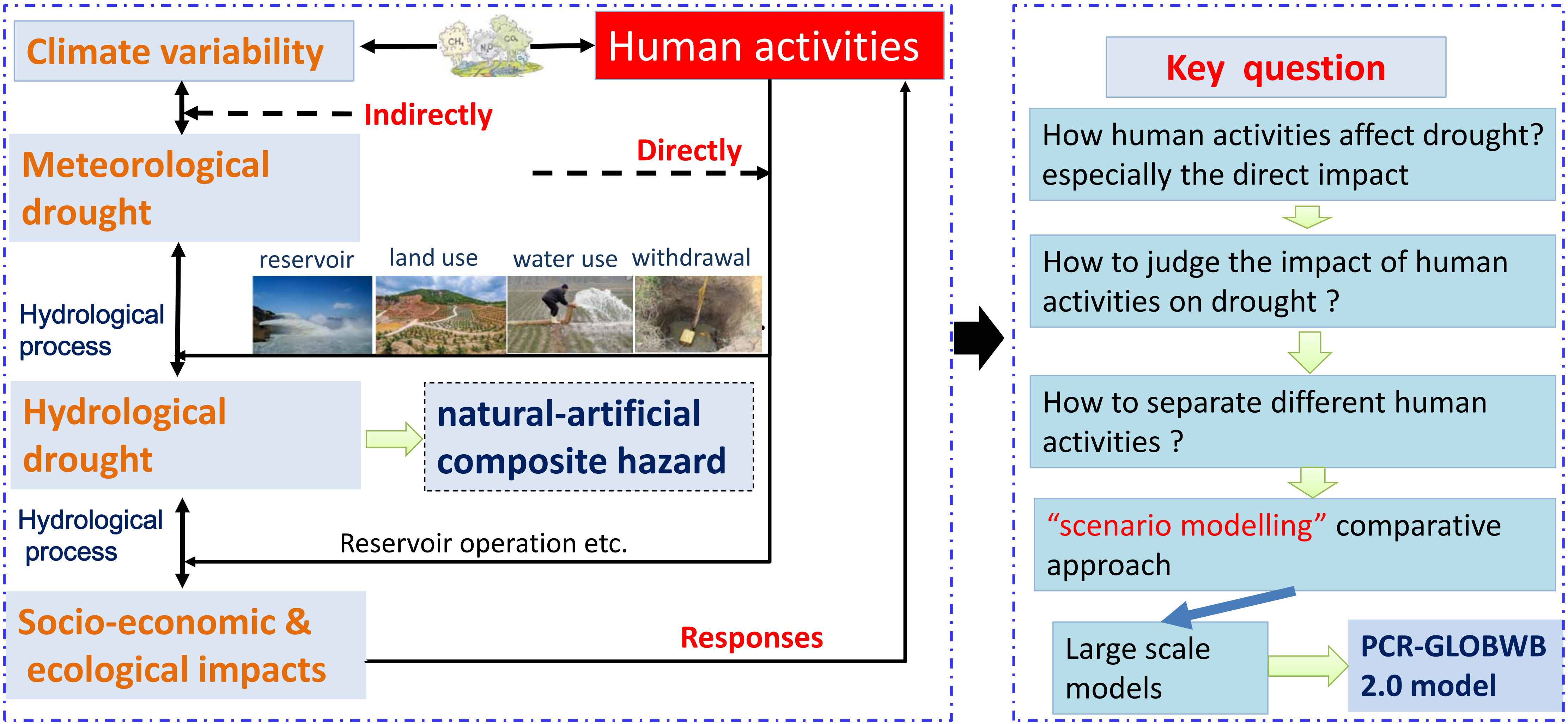
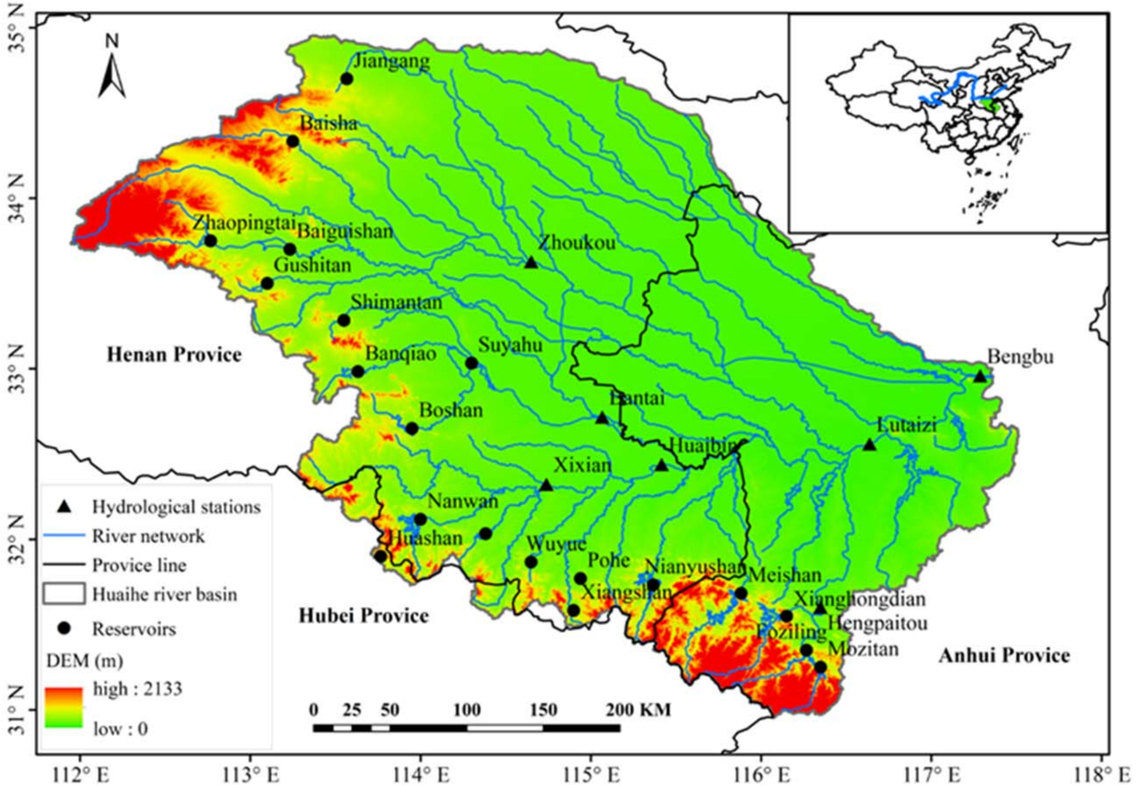


2 Study area and datasets

2.1 Study area and datasets

Study area



The catchment above Bengbu in Huaihe River Basin, China

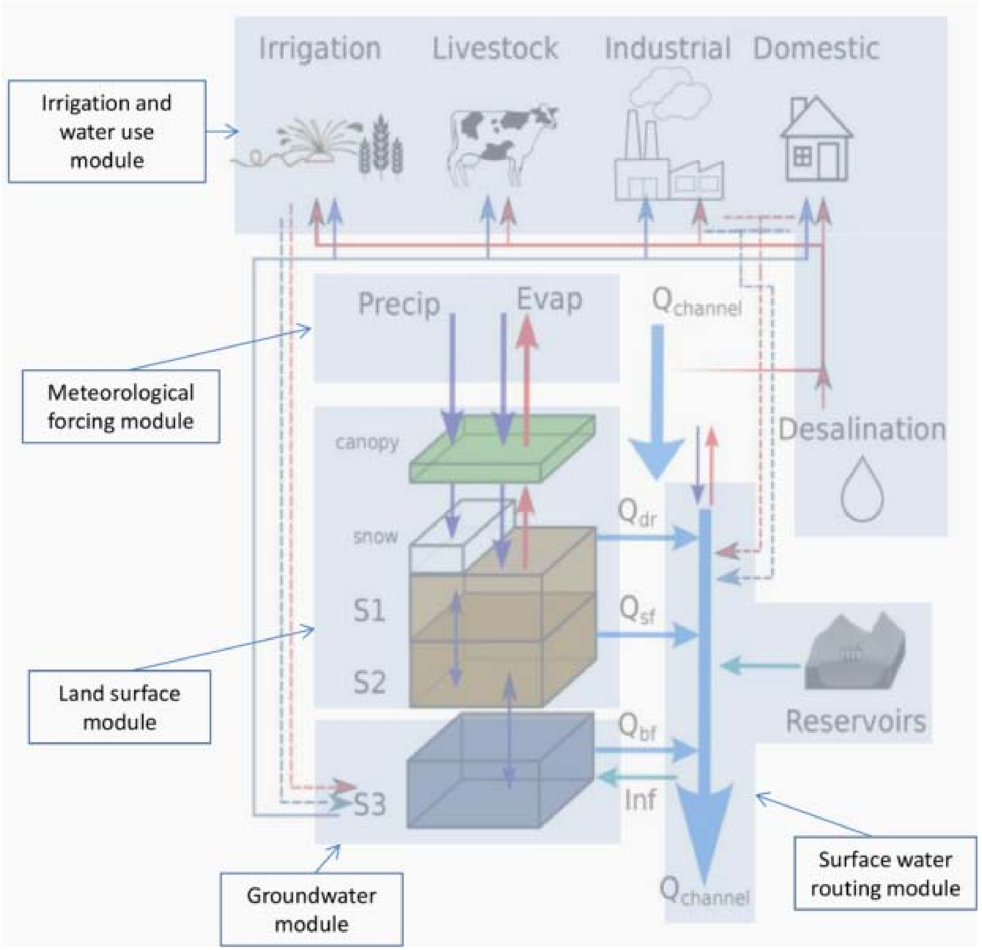
Major Datasets used in this study

Data	Source
Meteorological data (CMFD)	https://data.tpdc.ac.cn/zh-hans/ He et al.,2020
PCR-GLOBWB global dataset	Sutanudjaja et al. (2018)
Monthly discharge	Bureau of hydrology and water resources of Henan Province
Human activities e.g. water use and withdrawal, reservoir	Bureau of hydrology and water resources of Henan Province; Huaihe River Conservancy Commission

3 Methodology

3.1 PCR-GLOBWB 2.0 model

- PCR-GLOBWB 2.0 model is a state-of-the-art grid-based global hydrology and water resources model developed at Utrecht University
- For each grid cell (5 acrmin) and daily step, PCR-GLOBWB 2 simulates moisture storage in two vertically stacked upper soil layers as well as the water exchange among the soil, the atmosphere, and the underlying groundwater reservoir.
- PCR-GLOBWB 2.0 fully integrates water use and reservoir operation into hydrological model, and can systematically consider the direct impact of different human activities.



Structure of PCR-GLOBWB 2.0 (Sutanudjaja et al., 2018**)**

3.2 Model Calibration and validation

Adjusted parameters:

Meteorological forcing

China meteorological forcing dataset (CMFD)

Adjusted using spatially uniform pre-factors based on observed water demand, once determined not changed

Water demand data

Gross water demand	GWD	$f_{GWD} \in \{\cdots, 0.8, 0.9, 1, 1.1, 1.2, \cdots\}$	$GWD = f_{GWD} \times GWD_{\text{global}}$
Net water demand	NWD	$f_{NWD} \in \{\cdots, 0.8, 0.9, 1, 1.1, 1.2, \cdots\}$	$NWD = f_{NWD} \times NWD_{global}$

Calibrated parameters:

Calibrated using spatially uniform pre-factors based on observed discharge， the KGE was selected as the objective function to maximize for the calibration runs

Soil and groundwater parameters

Minimum soil water capacity	W_{min}	$f_w \in \{\cdots, 0.8, 0.9, 1, 1.1, 1.2, \cdots\}$	$W_{\min} = f_w \times W_{\max} = f_W \times (SC_1 + SC_2)$
Upper soil saturated hydraulic conductivities	K_{sat1}	$f_k \in \{\cdots, -0.15, -0.5, 0, 0.5, 0.15, \cdots\}$	$\log(K_{sat1}) = f_k + \log(K_{sat1_{\text{global}}})$
Lower soil saturated hydraulic conductivities	K_{sat2}	$f_k \in \{\cdots, -0.15, -0.5, 0, 0.5, 0.15, \cdots\}$	$\log(K_{sat2}) = f_k + \log(K_{sat2_{\text{global}}})$
Baseflow recession coefficient	J	$f_k \in \{\cdots, -0.15, -0.5, 0, 0.5, 0.15, \cdots\}$	$\log(J) = f_j + \log(J_{\text{global}})$

3.3 Experimental Setup

Seven human water management scenarios were conducted in this study:

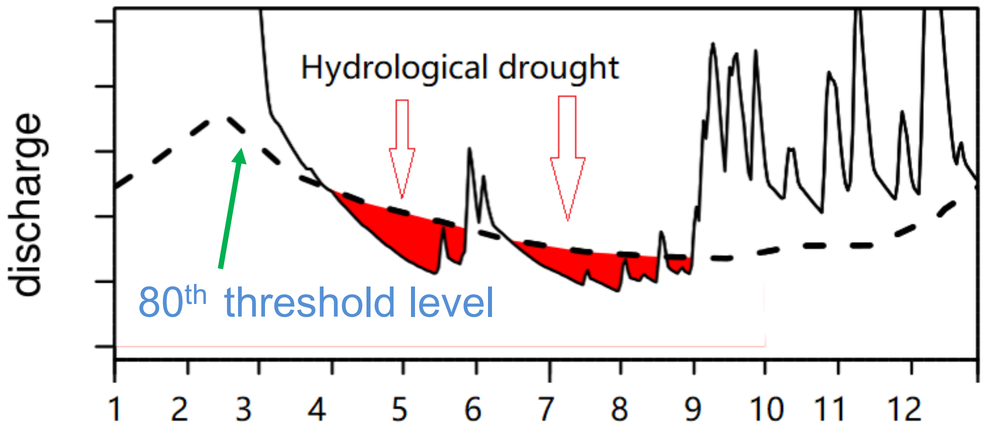
Simulated scenarios	Symbol	Implication
Natural S0	S0	Without human water use, without irrigation water use, without reservoir operations
Non-irrigation water use S1	S1(a)	Consider non-irrigation water use (industrial, domestic and livestock water use)
	S1(b)	Consider non-irrigation water use (industrial, domestic and livestock water use) and reservoir operations
Irrigation water use S2	S2(a)	Consider irrigation water use
	S2(b)	Consider irrigation water use and reservoir operations
Human S3	S3(a)	Consider all human water use but no reservoirs operation (industrial, domestic, and livestock water use , and irrigation water use)
	S3(b)	Consider all human activities(includes industrial, domestic, and livestock water use , irrigation water use, and reservoirs operations)

The each human scenario was compared to natural scenario (S0) respectively to quantify the impact of various human activities on drought characteristics:

$$\text{Relative Contribution} = \frac{\text{Human}-\text{Natural}}{\text{Natural}} \times 100\%$$

3.4 Calculation of drought characteristics

- The variable threshold method (VTM) was used to extract drought characteristics from simulated discharge.
- The 80th percentile of monthly average($Q_{80\%}$) was selected as threshold level.
- To determine the impact of humans on drought, the monthly discharge simulated by natural scenario was selected as the threshold selection object



Identify drought

$$Ds(t,n)=\begin{cases}1, & Q(t,n)<Q_{80\%}(t,n)\\ 0, & Q(t,n)\geq Q_{80\%}(t,n)\end{cases}$$

Drought area

$$Darea(t)=\frac{\sum_{n=1}^{N}Ds(t,n)}{N}$$

Drought duration

$$Ddur_{i,n}=\sum_{t=S_i}^{E_i}Ds(t,n)$$

standardized drought deficit

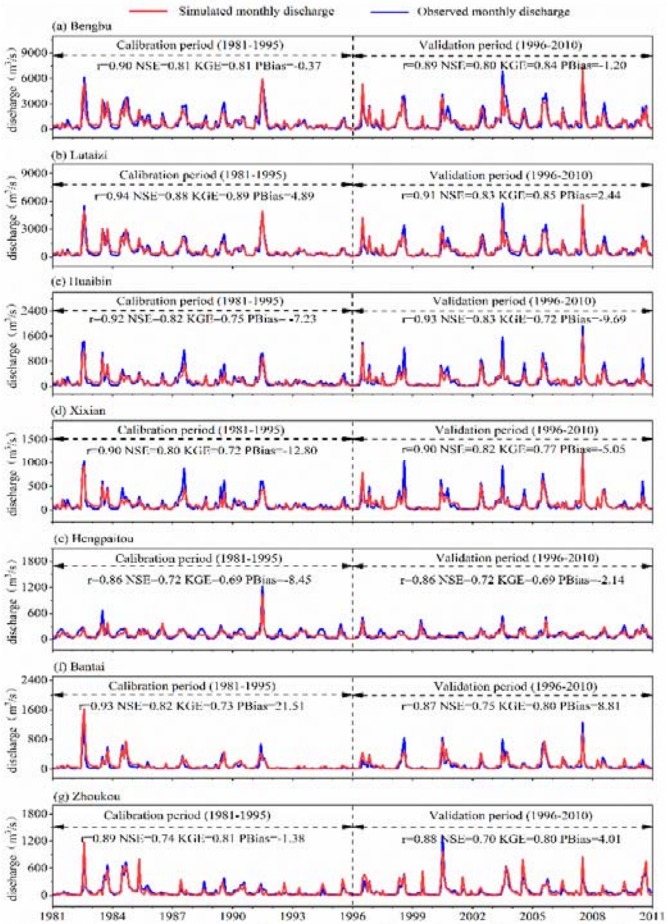
$$StDef(t,n)=\frac{\max\left(Q_{80\%}(t,n)-Q(t,n),0\right)}{Q_{80}(t,n)}$$

Calculation Process of Drought Characteristics

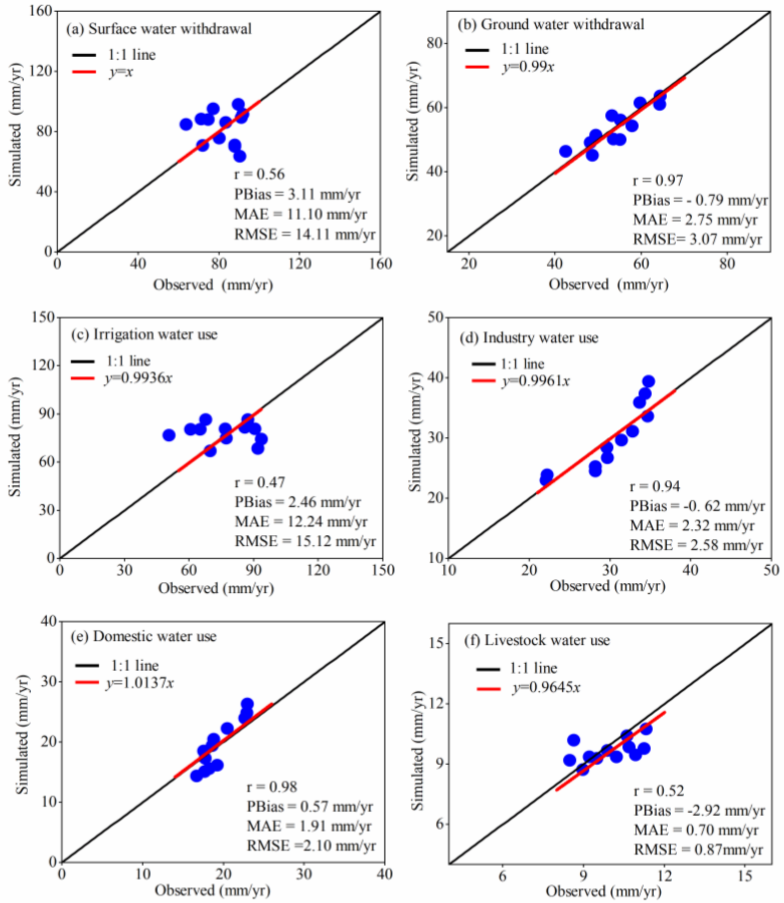
4 Results

4.1 Model Evaluation

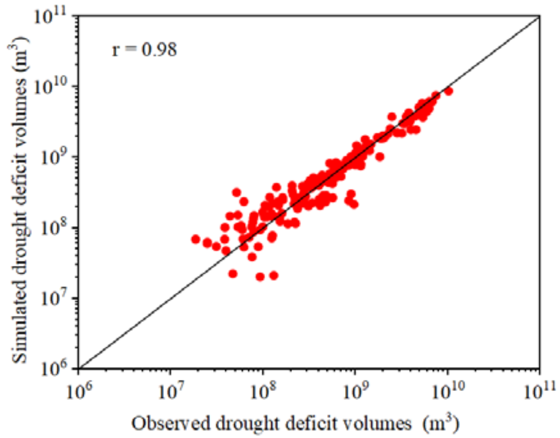
Performance of discharge simulation



Performance of water use and withdrawal simulation



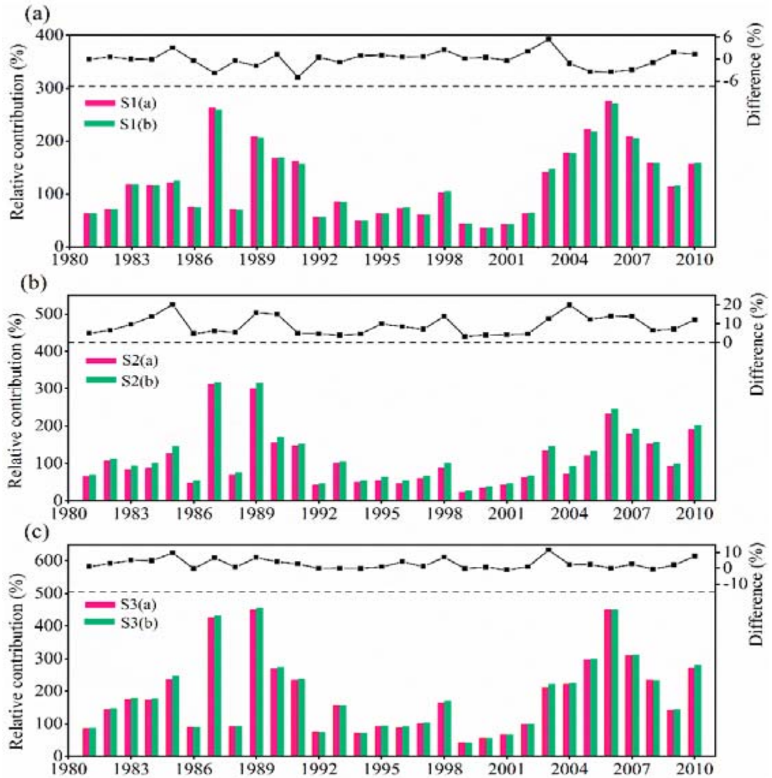
Performance of drought deficit volumes simulation



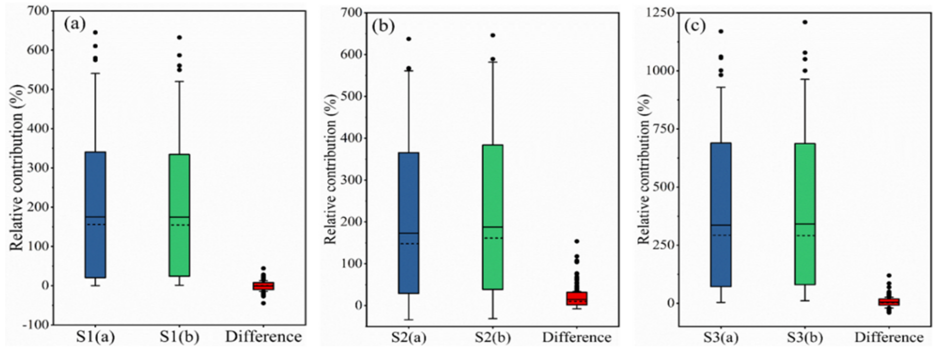
- It can be found that the calibrated model is able to simulate discharge, water use and drought deficit under low flow condition.

4.2 Impacts of humans on droughts during 1981-2010

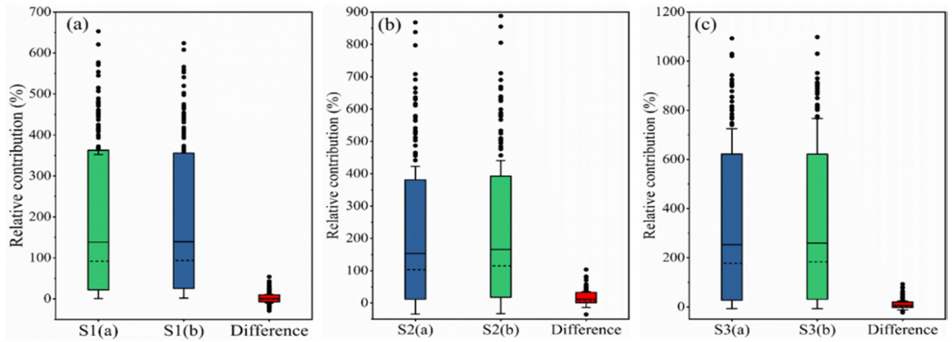
Impacts of each human on drought duration per year



Impacts of each human on monthly stDef



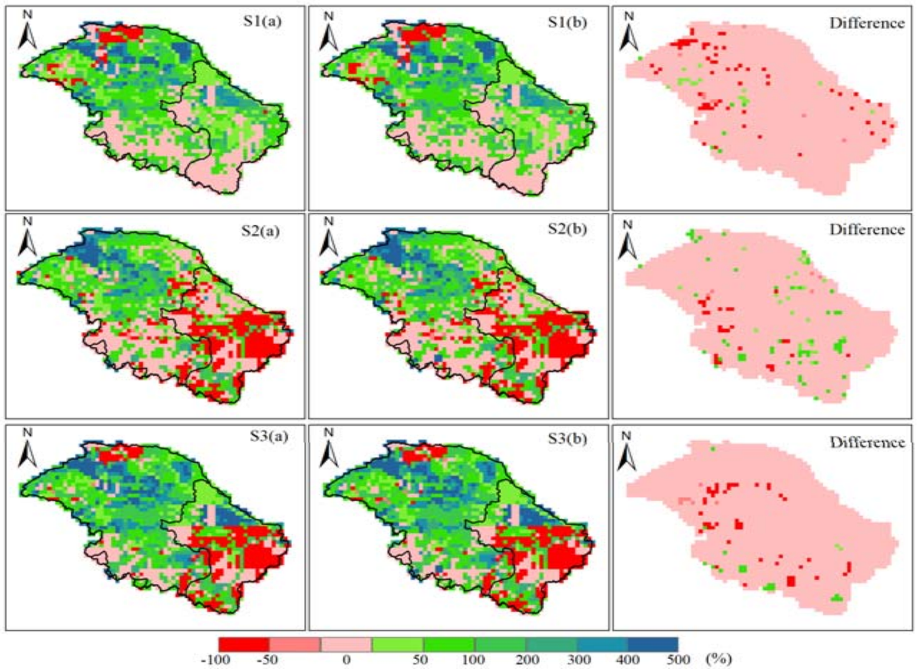
Impacts of each human on monthly drought area



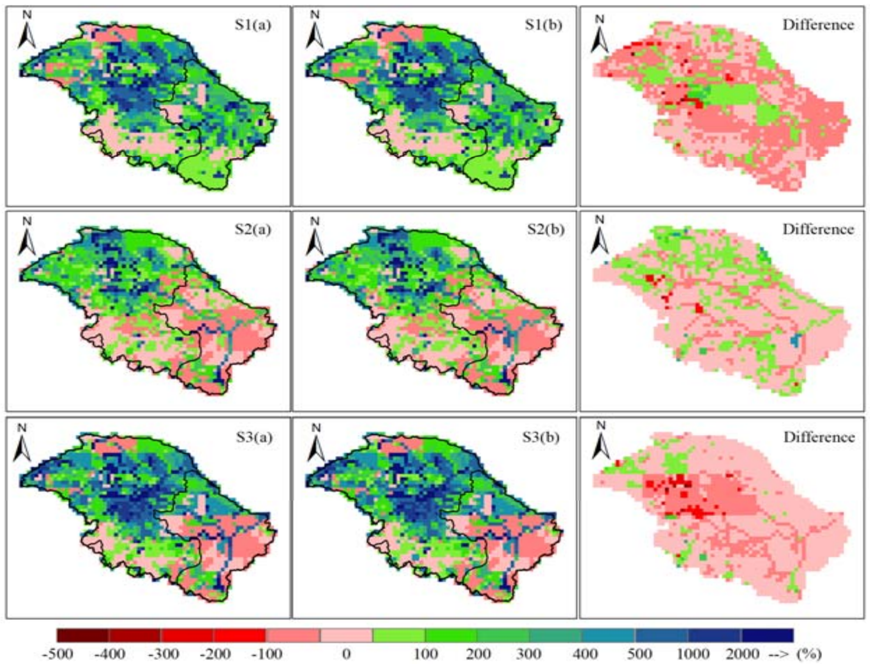
Note: (a)Non-irrigation S1; (b) Irrigation S2; (c) Human S3.Without reservoir operation(a) and with reservoir operation (b) were considered. The difference indicates the impact of reservoir operation on drought.

4.3 Impacts of humans on 2008-2009 autumn-winter drought

Spatially impact of each human on drought duration



Spatially impact of each human on StDef



Note: (a)Non-irrigation S1; (b) Irrigation S2; (c) Human S3.Without reservoir operation(a) and with reservoir operation (b) were considered. The differences indicates the impact of reservoir operation on drought.

5 Conclusions

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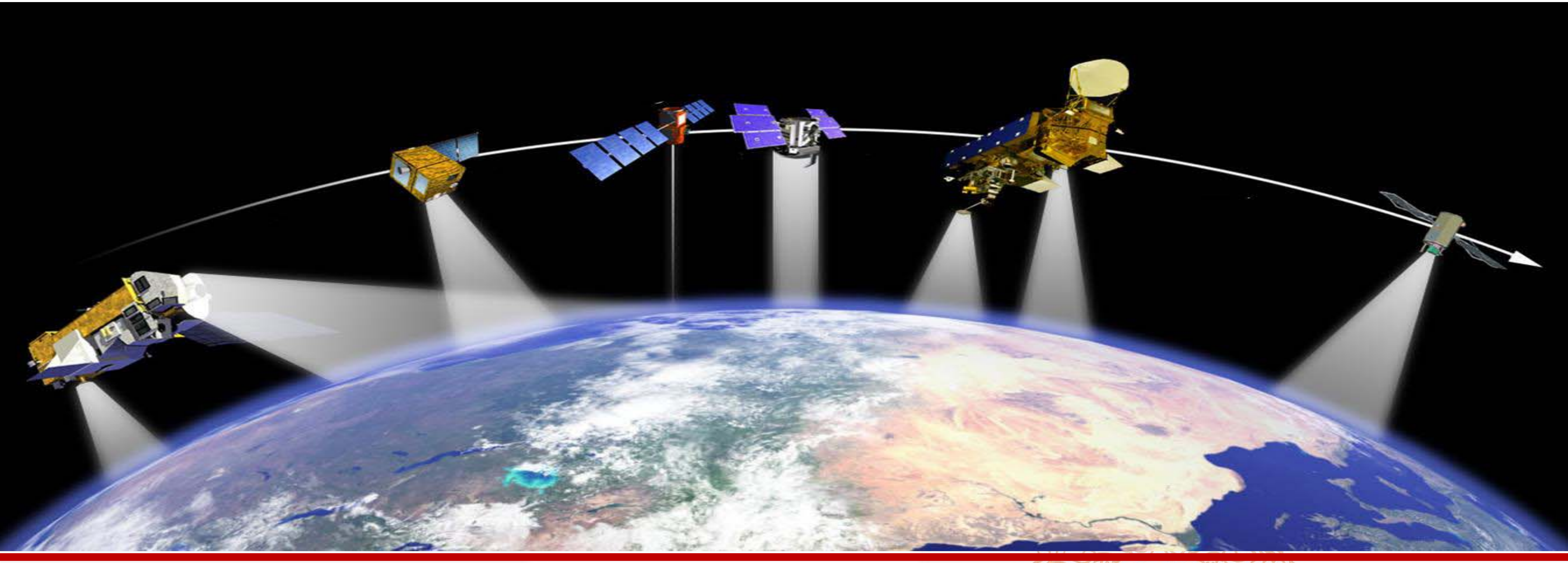
- During 1981-2010, human water use significantly amplified hydrological droughts. For entrance, irrigation water use, non-irrigation water use and combination of irrigation and non-irrigation water use increased StDef by about 173%, 175%, and 336% on average, respectively. Differently, when the reservoirs were regulated for drought resistance, it had negative impacts on drought, while reservoirs were regulated for other functions, it had positive impact on drought.

- However, during 2008-2009 autumn-winter drought , reservoirs operation aggravated the drought in the upstream as well as mitigated the drought in the downstream. In addition, irrigation and non-irrigation had different spatial impacts on drought because of different water use patterns and seasonal characteristics, although the magnitude of this drought were heavily exacerbated by water use.

- Our results suggests that different human activities have different impacts on hydrological drought in time and space. Therefore, the findings of this different impact can help provide a decision-making basis for drought management under the human-modified era.



Thank you!