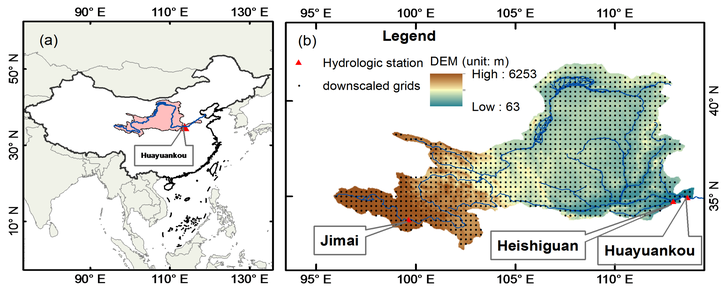
Prediction and Projection of Runoff and Hydrological Extremes for the Yellow River Basin in China

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Abstract: S2S runoff prediction with one-way coupled climate model and hydrological model was explore, and the changes in runoff, floods, droughts and ecological flows were projected under SSP245, SSP370 and SSP585 for the 21th century for the Yellow River Basin, China.

☐ Study area



Location of (**a**) the Yellow River Basin and (**b**) three hydrological stations, together with basin topography and the grid with resolution of 0.25°×0.25°

The Yellow River has been threated by water shortage, with less tan 500 m3 of water per capita. Annual average temperature is 8–11℃, and the annual mean precipitation is 340–700 mm.

☐ Atmospheric Forcing

CMIP6 GCMs

No.	GCMs	Institute	Resolution latitude×longitude
1	ACCESS-CM2	Commonwealth Scientific and Industrial Research Organization and and Bureau of MeteorologyAustralian Research Council Centre of Excellence for Climate System Science (Australia)	1.2°×1.8°
2	ACCESS-ESM-1-5	Commonwealth Scientific and Industrial Research Organization (Australia)	1.2°×1.8°
3	BCC-CSM2-MR	Beijing Climate Center, China Meteorological Administration (China)	1.1°×1.1°
4	CCCma-CanESM5	Canadian Centre for Climate Modelling and Analysis, Environment and Climate Change Canada (Canada)	2.8×2.8
5	CNRM-CM6-1	Centre National de Recherches Météorologiques, Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique (France)	1.4×1.4
6	CNRM-ESM2-1		1.4×1.4
7	HadGEM3-GC31-LL	Met Office Hadley Centre (United Kingdom)	1.3×1.9
8	INM-CM4-8	Institute of Numerical Mathematics (Russia)	1.5×2.0
9	INM-CM5-0		1.5×1.5
10	IPSL-CM6A-LR	Institut Pierre-Simon Laplace (France)	1.3×2.5
11	MIROC6	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology (Japan)	1.4×1.4
12	MPI-ESM1-2-HR	Max Planck Institute for Meteorology (Germany)	0.9×0.9
13	MRI-ESM2-0	Meteorological Research Institute (Japan)	1.1×1.1

CMA-CPSv3 S2S

Daily forecast; 2008-, Ensemble: 4 members daily

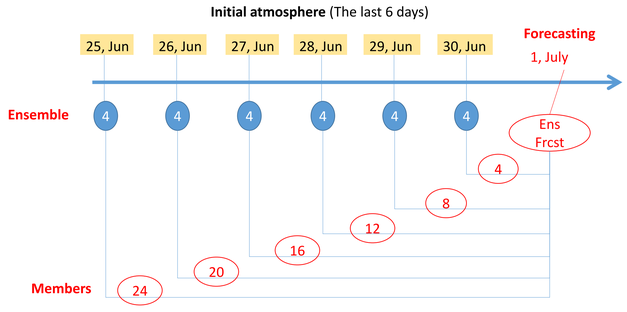
BCC_AGCM3(T266~45km, L56)

BCC_AVIM1.0(T266)

MOM4-L40v2(1/4°~25 km)

SISv1 (1/4°~25km)

☐ S2S runoff prediction



☐ Hydrological model: HBV-D

Station	Period	E_{ns}	R^2	PBIAS(%)
Huayuankou	Calibration (1952–1990)	0.74	0.86	3.9
	Verification (1991–2012)	0.71	0.86	5.3
Jimai	Verification (1959–1997)	0.55	0.78	22
Heishiguan	Verification (1970–2000)	0.72	0.88	18

Drought predication:

$$p_{drought} = \frac{\sum_{i=1}^{N}\sum_{j}^{M} f(R_{ij})}{N \times M},$$

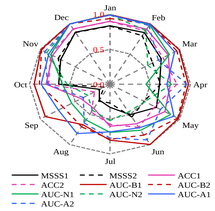
$$f(R_{ij}) = \begin{cases} 1, if\ R_{ij} \ll Threshld_{drought} \\ 0, if\ R_{ij} > Threshld_{drought} \end{cases}$$

P- probability of drought;
$Threshld_{drought}$ – threshold of drought; N – days precdited ; M – size of ensemble

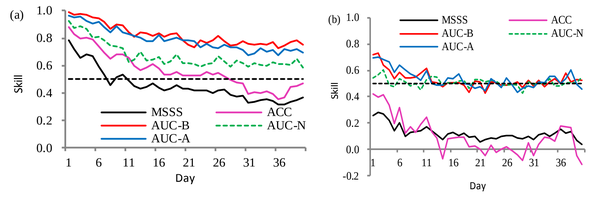
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☐ Skill of S2S runoff prediction



MSSS, ACC and for the runoff (1, 2 represent for the 1-30 days and 11-40days)



Mean daily skill score of MSSS, TCC and AUC of runoff (a) and precipitation (b)

BSS for droughts

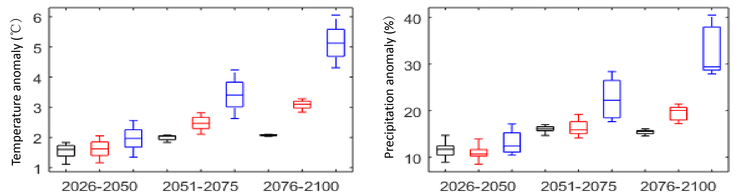
threshold	Jan	Feb	Nov	Dec
15%	0.986	0.874	0.997	0.998
10%	0.936	0.774	0.998	0.920

BSS for floods

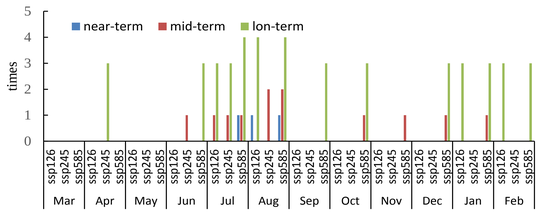
flood	Jul	Aug
10%	0.122	0.313
5%	0.043	0.394

- The skill is higher in dry season than wet season, highest for above-normal tercile, but lowest for normal tercile.
- The skill is higher for runoff than for precipitation.
- Extreme drought prediction is skillful in November and the months in winter (DJF).
- Skill if higher for droughts than floods, and higher for more frequent events than for less frequent events.

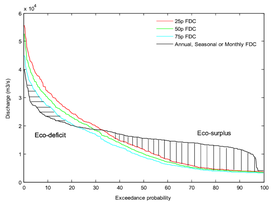
☐ Runoff projection in the 21st century

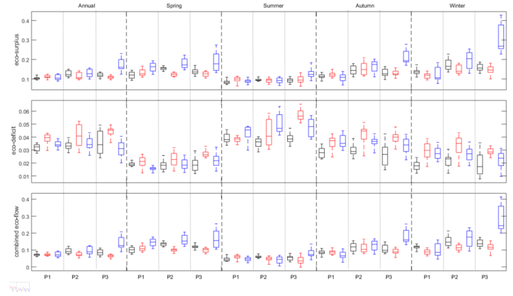


Annual mean precipitation and temperature (black: SSP1-2.6, Red: SSP2-4.5, blue: SSP5-8.5)



Times of hydrological droughts (SRI-12) exceeding the historical maximum intensity

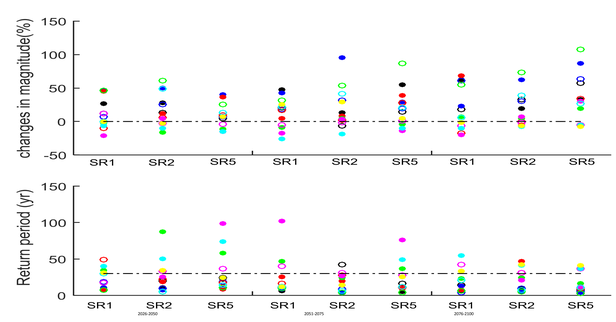




- The increasing trends of annual mean temperature and annual precipitation will be significant from 2026 to 2100 with the smallest rate under SSP1-2. 6 but the largest rate under SSP5-8. 5.
- Annual runoff will slightly increase, the Yellow River Basin will be contentiously threatened by water shortage under scenarios SSP245, SSP370 and SSP585.

Projected changes in runoff

Period	Per Capita Annual Runoff: Median [min, max] (m^3)		
	SSP1–2.6	SSP2–4.5	SSP5–8.5
2026–2050	541 [373, 746]	511 [345, 826]	524 [399, 861]
2051–2075	607 [450, 1098]	528 [359, 1102]	641 [394, 1028]
2076–2100	788 [478, 1318]	583 [428, 1112]	828 [552, 1999]



Projected magnitude and return period of 1-in-30-years floods

Multi-models mean of annual and seasonal eco-surplus, eco- deficit and net eco-flow (P1：2026-2050，P2：2051-2050，P3-2051-2100；black：SSP1-2.6，red：SSP2-4.5，blue：SSP5-8.5)

- The Yellow River Basin will experience larger and more frequent floods in the future.
- Climate change will offset the negative impacts of human activities on, with the most under scenario SSP5-8. 5, and the most in winter but the least in summer and autumn.

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