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Insights into uncertainties in future drought analysis using hydrological simulation model

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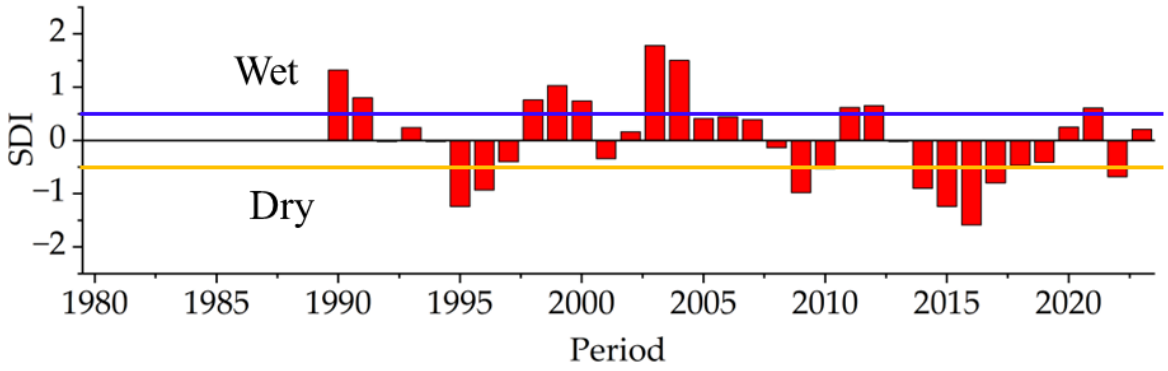
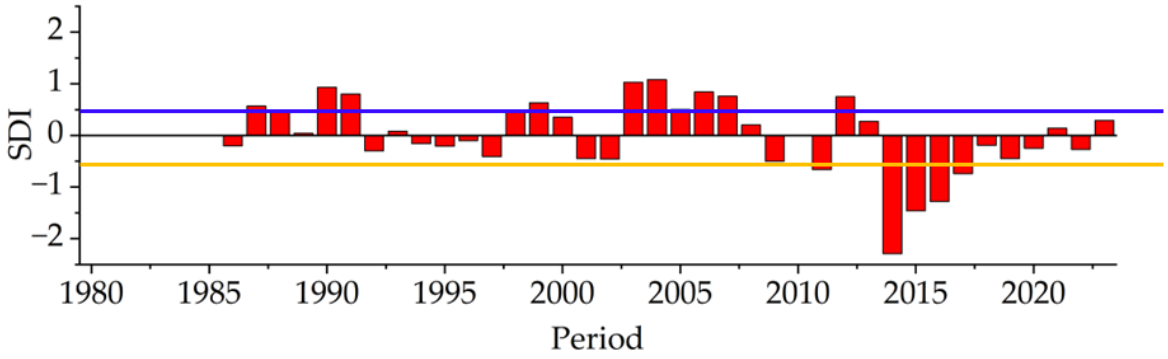
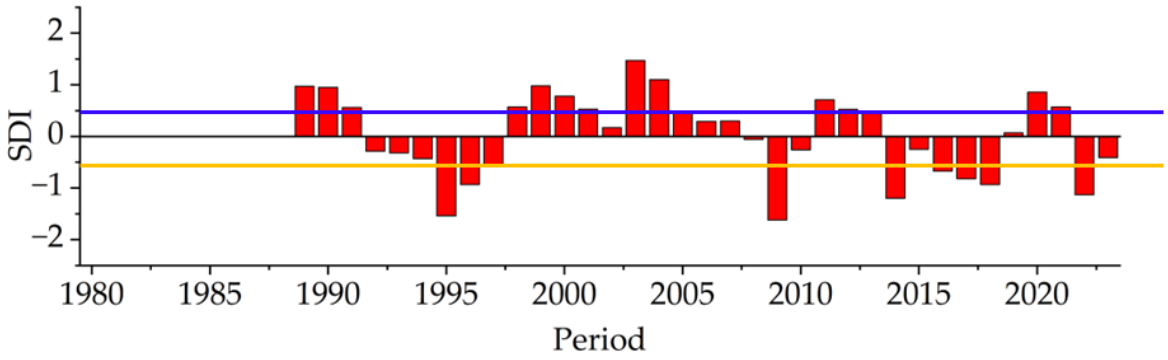


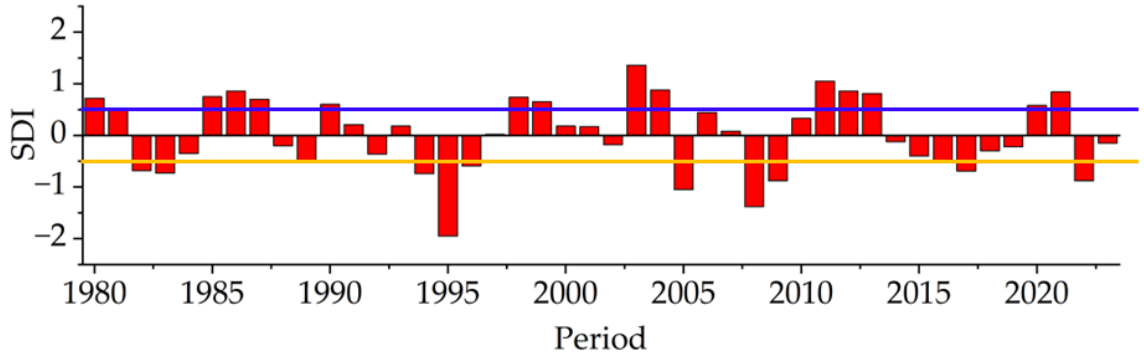
(a) AD



(b) CJ

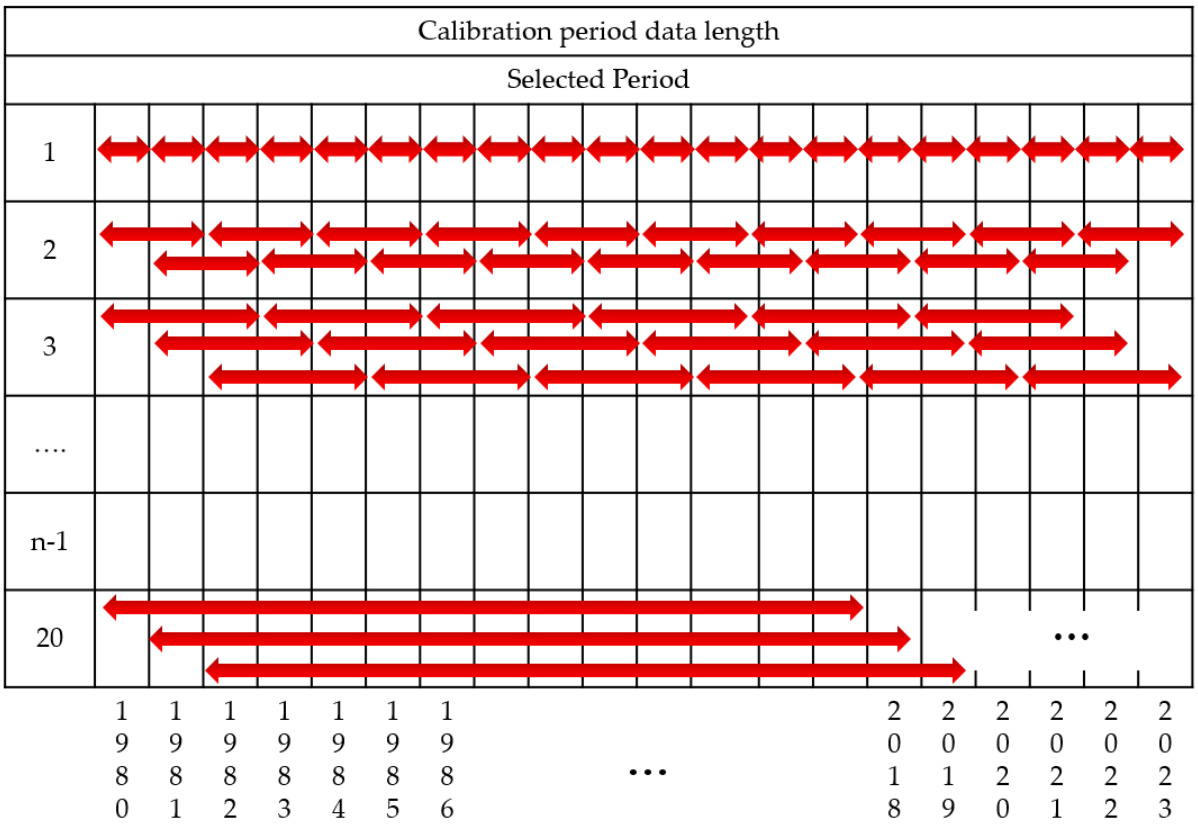


(c) HCH



(d) SJ

Figure S. 1. Hydrological conditions defined by Streamflow Drought Index for the historical period



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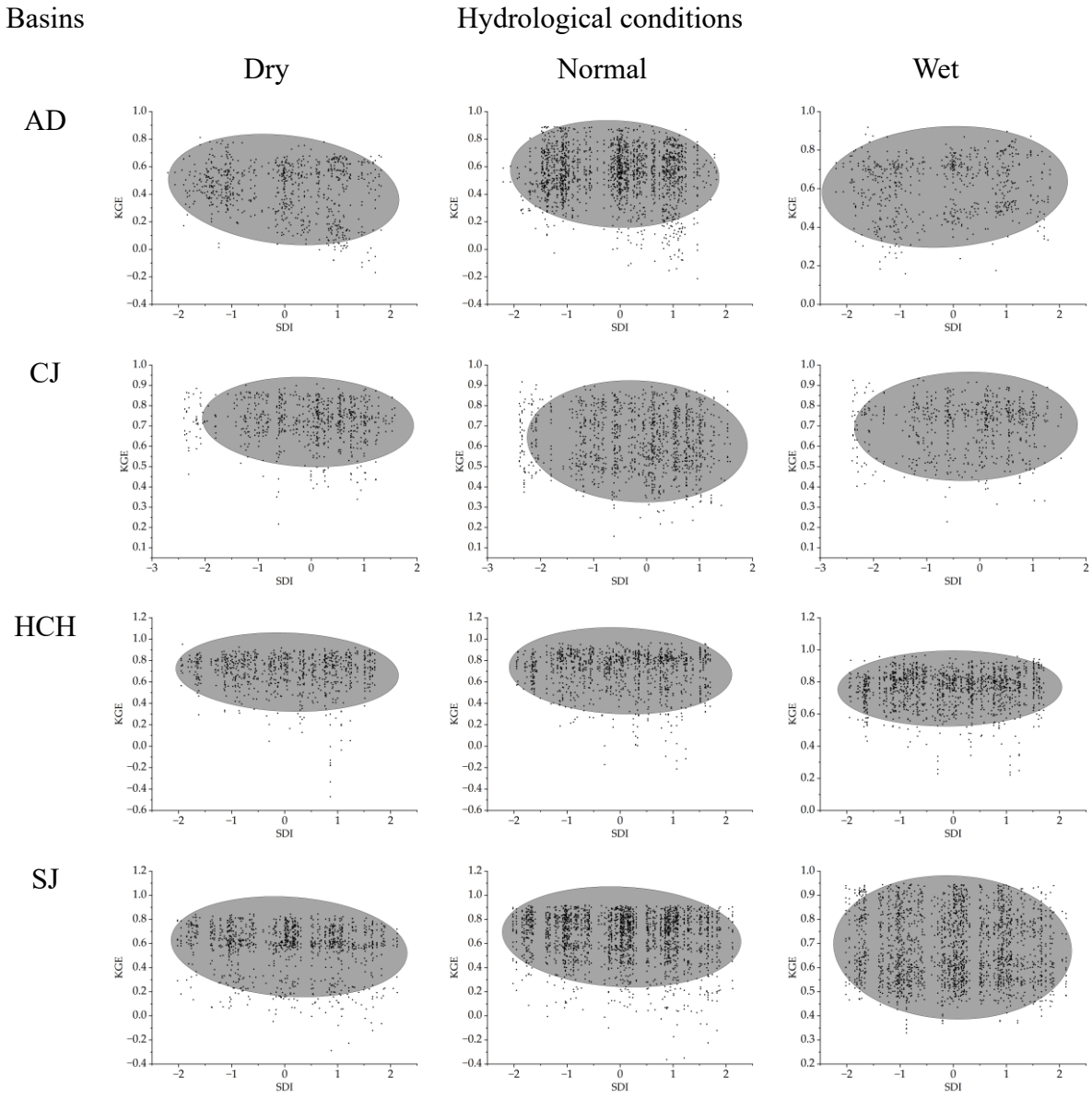
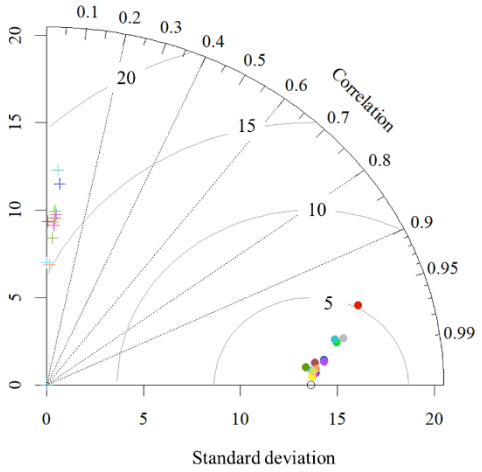
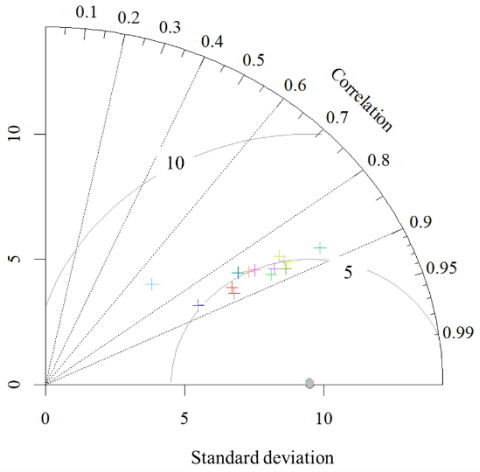


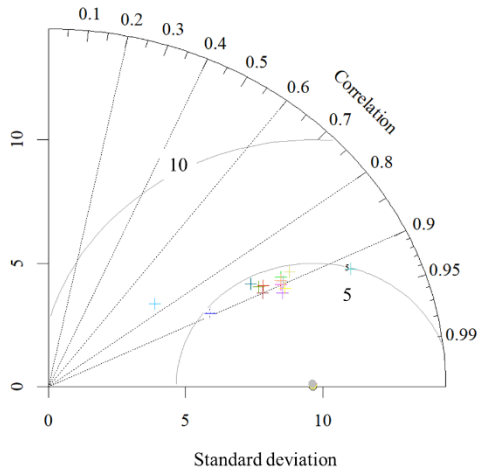
Figure. S. 3. KGEs for hydrological conditions classified by SDI (ellipse indicates confidence level 90% (prediction))



(a) Precipitation



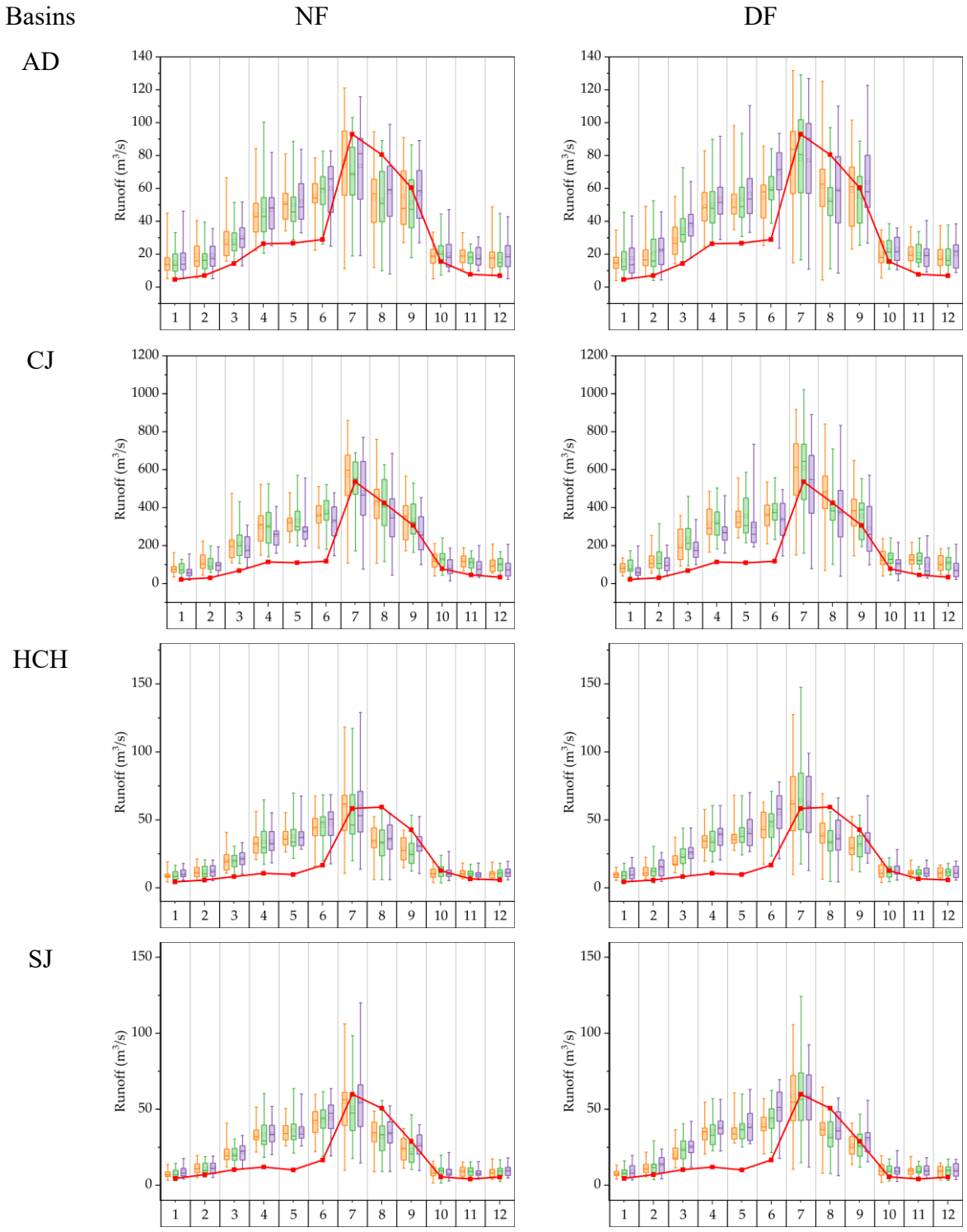
(b) Max temperature



(a) Min temperature

legend

Figure. S. 4. Comparison of before and after bias-corrected GCM data against observed data using a Taylor diagram


Basins
NF
DF
AD
CJ
HCH
SJ
Runoff (m³/s)
1
2
3
4
5
6
7
8
9
10
11
12

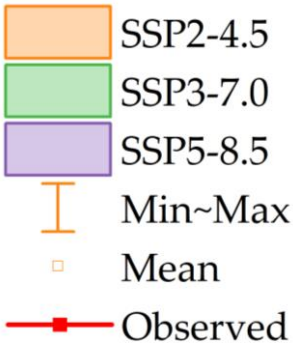


Figure. S.5. Projected annual changes in future runoff (m^3/s)

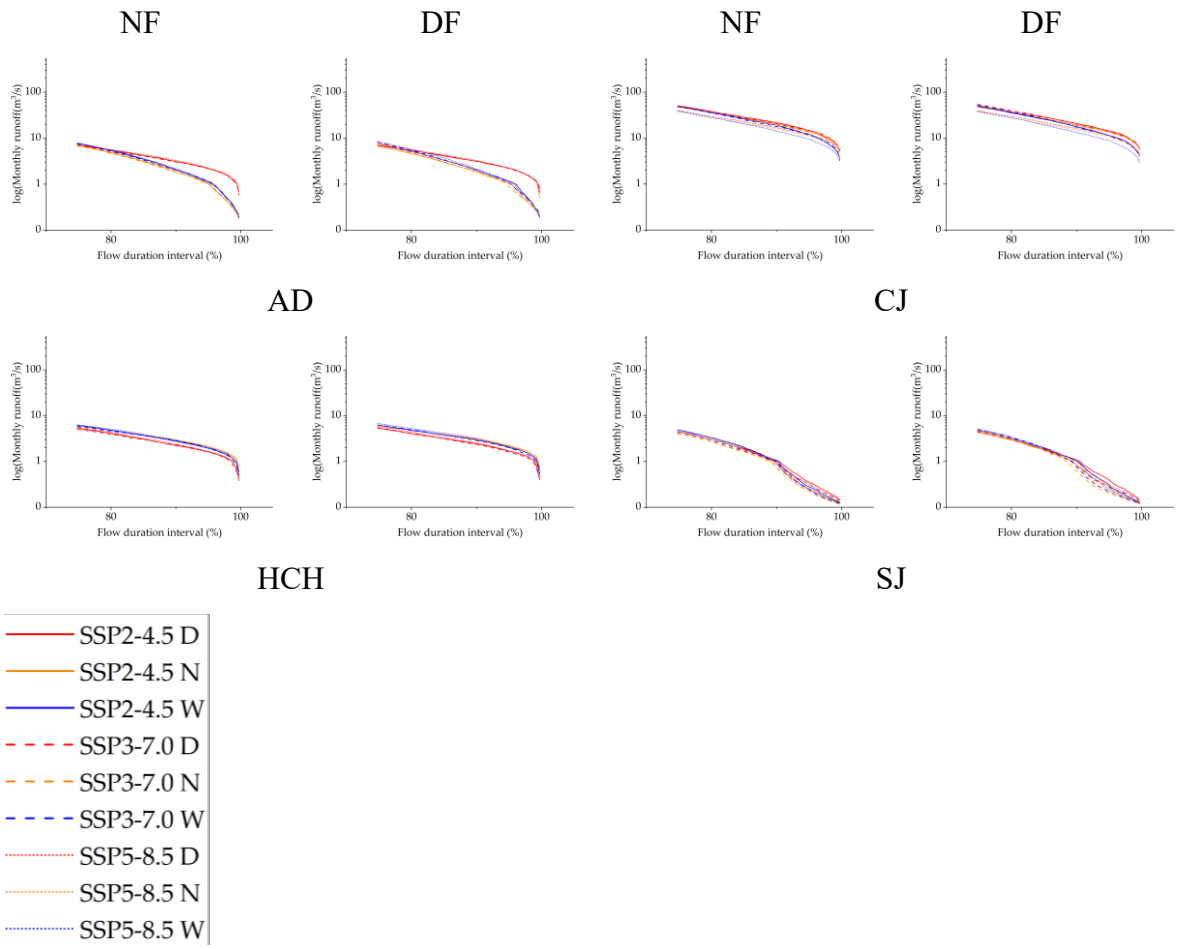


Figure. S.6. Flow duration curves of projected future low flow

Figure. S. 7. Validation of statistical assumptions for the ANOVA models for the NF, showing representative Q-Q plots and Residuals vs. Fitted plots

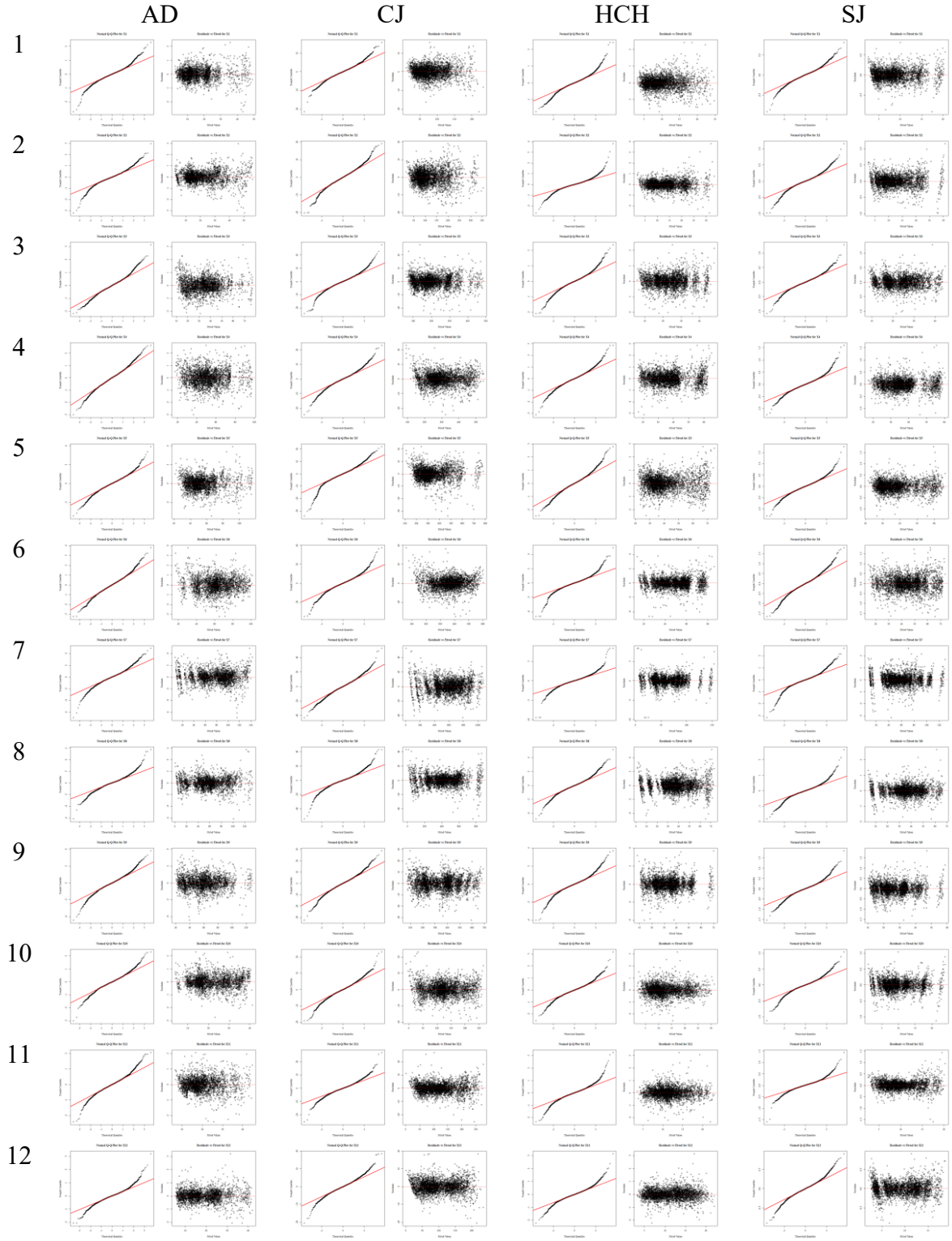
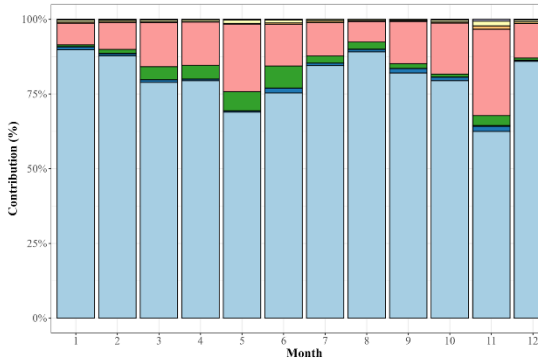
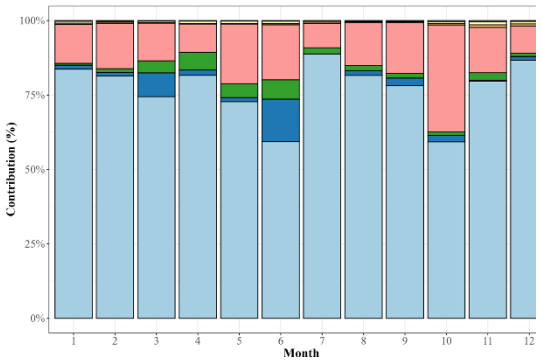
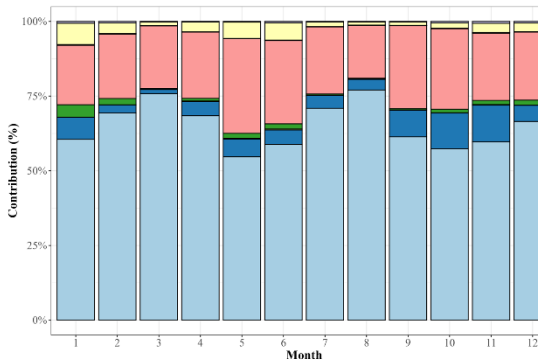
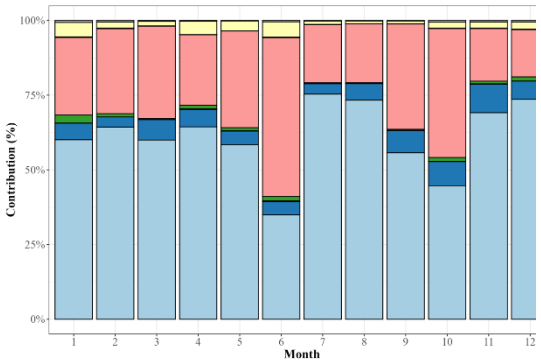
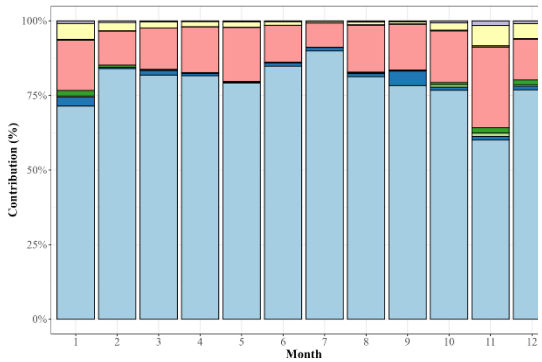
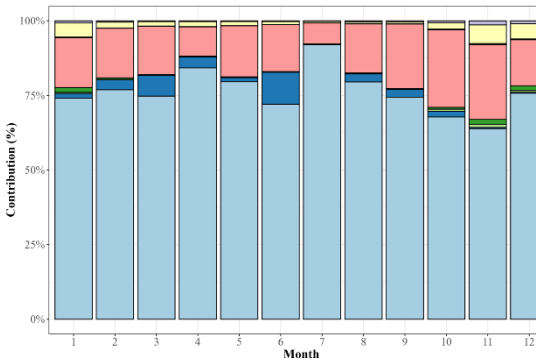
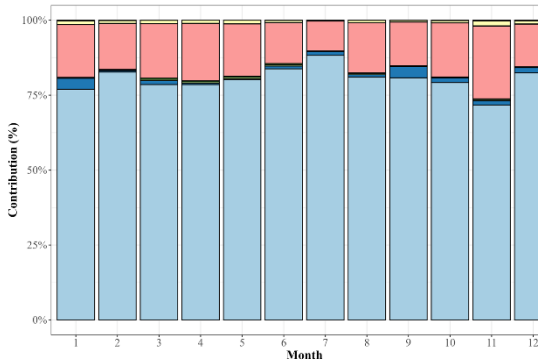
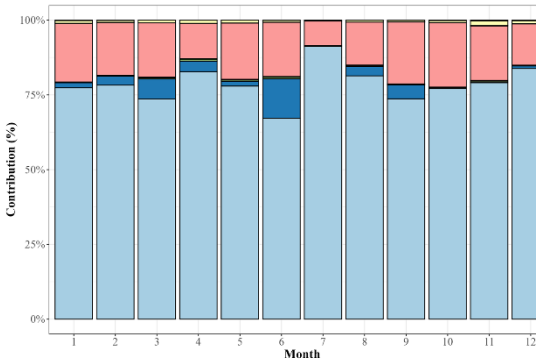


Figure. S. 8. Validation of statistical assumptions for the ANOVA models for the DF, showing representative Q-Q plots and Residuals vs. Fitted plots

Basins	NF	DF
AD		
CJ		
HCH		
SJ		

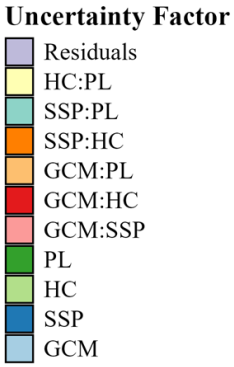


Figure. S. 9. Contribution of the four sources to uncertainty in the future runoff projection

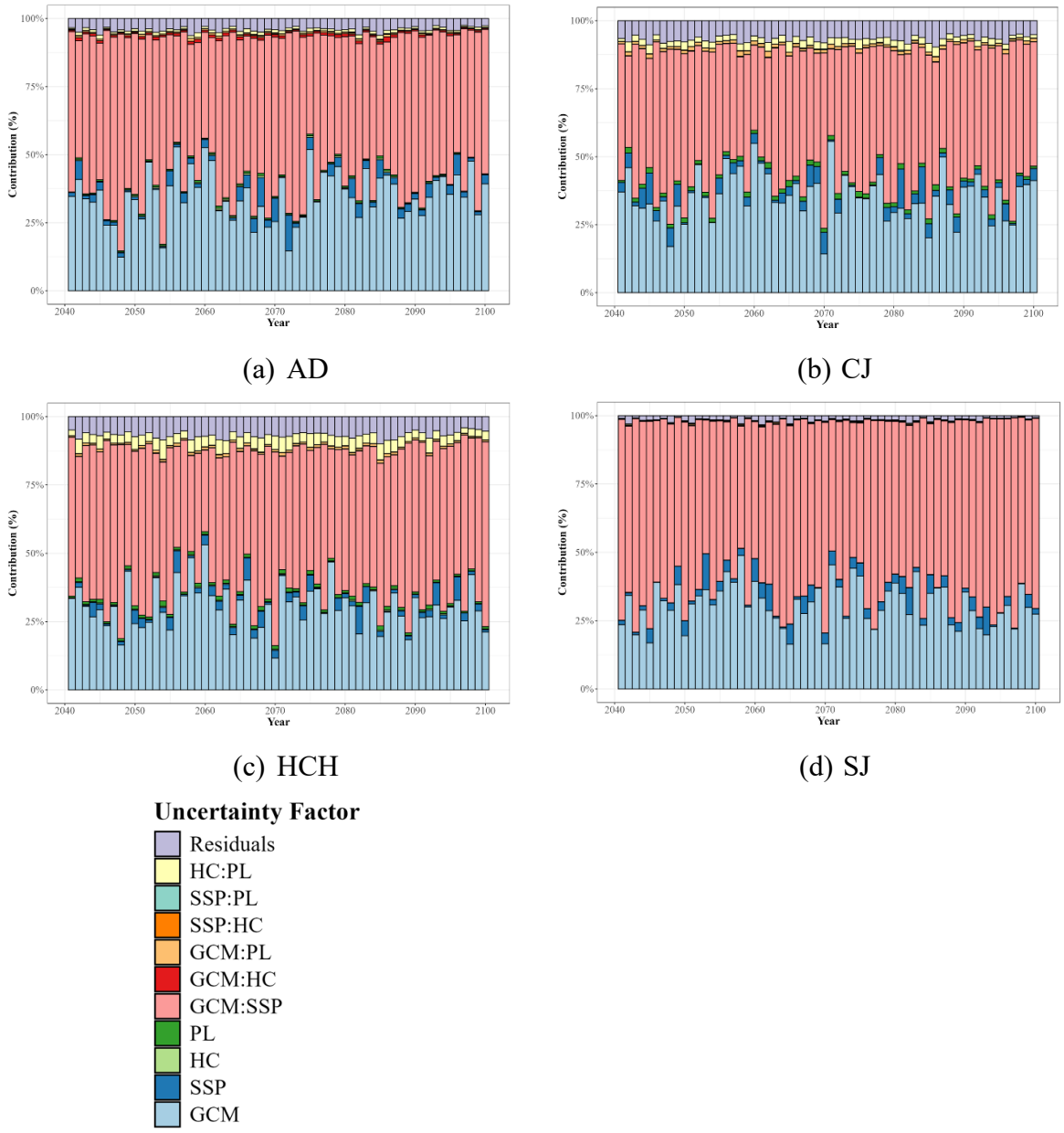


Figure. S. 10. Contribution of the four sources to uncertainty in the future hydrological drought

List of Table as Supplementary Material

Table S1. Information of study area

Basins	Area (km^2)	Aver. Temp (°C)	Aver. Prec. (mm)	Urban ratio (%)	Forest ratio (%)
AD	1,584	12.2	1,045.7	0.7	78.8
CJ	6,648	11.7	1,214.3	5.3	61.7
HCH	925	13.2	1,289.9	2.0	78.3
SJ	763	13.3	1,329.8	1.5	75.4

Table S2. Information on CMIP6 GCMs used in this study

No	Institution	Model	Resolution (long × lat)
M1	Australia Commonwealth Scientific and Industrial Research Organization	ACCESS-CM2	1.875° × 1.25°
M2		ACCESS-ESM1-5	
M3	China Beijing Climate Centre,	BCC-CSM2-MR	1.125° × 1.125°
M4	Canada Canadian Centre for Climate Modelling and Analysis	CanESM5	2.8° × 2.8°
M5	Italy Euro-Mediterranean Centre on Climate Change	CMCC-ESM2	1.25° × 0.9°
M6	Netherlands, Ireland EC-EARTH consortium	EC-Earth3	0.7° × 0.7°
M7		EC-Earth3-Veg	
M8		EC-Earth3-Veg-LR	
M9	China Chinese Academy of Sciences,	FGOALS-g3	2.0° × 2.25°
M10	USA NOAA Geophysical Fluid Dynamics Laboratory	GFDL-ESM4	1.25° × 1.0°
M11	Russia Institute for Numerical Mathematics	INM-CM4-8	2.0° × 1.5°
M12		INM-CM5-0	
M13	France Institute Pierre-Simon Laplace	IPSL-CM6A-LR	2.5° × 1.26°
M14	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute for Environmental Studies	MIROC6	1.4° × 1.4°
M15	Germany Max Planck Institute for Meteorology,	MPI-ESM1-2-HR	0.93° × 0.93°
M16		MPI-ESM1-2-LR	1.87° × 1.87°
M17	Japan Meteorological Research Institute	MRI-ESM2-0	1.125° × 1.125°
M18	Norway Norwegian Climate Centre	NorESM2-MM	1.25° × 0.93°
M19		NorESM2-LM	2.5° × 1.87°
M20	Taiwan Research Center for Environmental Changes	TaiESM1	1.1° × 1.1°

Table S3. Projected climate variables and historical data

climate variable	period		Month											
			1	2	3	4	5	6	7	8	9	10	11	12
Prec. (mm)	Historical		19.3	26.8	48.0	70.5	84.6	126.8	237.9	220.8	118.8	42.7	33.4	18.2
	NF	SSP2 -4.5	36.5	47.8	83.1	118.9	136.1	150.7	195.8	153.5	118.4	51.3	51.5	44.2
		SSP3 -7.0	36.9	44.2	79.2	116.1	131.6	150.0	188.5	149.6	111.4	54.6	47.8	44.1

		SSP5 -8.5	36.1	44.9	78.4	117.9	134.0	154.8	195.5	158.0	115.9	51.5	46.0	43.0
	DF	SSP2 -4.5	38.1	46.1	84.8	127.8	138.9	148.7	207.9	164.8	126.8	54.4	53.2	45.3
		SSP3 -7.0	37.6	44.5	86.8	125.6	133.6	162.2	186.3	149.3	114.3	52.3	49.9	44.0
		SSP5 -8.5	41.0	48.0	95.2	130.1	144.4	169.6	197.3	151.3	127.4	49.5	51.9	46.7
Max Temp.	Historical		4.0	7.0	12.7	19.5	24.6	27.8	29.5	30.1	25.8	20.5	13.1	5.9
	NF	SSP2 -4.5	6.6	7.9	12.6	18.4	24.1	28.9	32.1	33.3	29.7	23.6	16.5	9.9
		SSP3 -7.0	6.8	8.1	12.8	18.5	24.2	29.0	32.3	33.5	30.0	23.8	16.6	10.1
		SSP5 -8.5	7.5	8.7	13.4	19.0	24.8	29.7	32.9	34.1	30.6	24.5	17.2	10.7
	DF	SSP2 -4.5	7.5	8.8	13.4	19.1	24.9	29.8	32.9	34.0	30.5	24.5	17.3	10.6
		SSP3 -7.0	8.4	10.0	14.5	20.1	25.7	30.7	33.9	35.3	31.8	25.6	18.5	11.7
		SSP5 -8.5	9.6	11.0	15.5	21.0	26.9	31.8	35.1	36.3	33.0	26.8	19.7	13.0
Min Temp.	Historical		-7.1	-5.0	-0.1	5.5	11.1	16.5	21.0	21.2	15.6	8.0	1.0	-5.3
	NF	SSP2 -4.5	-5.1	-4.1	0.5	6.0	11.7	17.4	22.3	23.4	19.1	11.9	4.5	-1.8
		SSP3 -7.0	-4.8	-3.7	0.7	6.3	11.9	17.7	22.6	23.7	19.4	12.2	4.7	-1.5
		SSP5 -8.5	-4.2	-3.2	1.2	6.7	12.4	18.3	23.1	24.2	20.1	12.8	5.3	-0.9
	DF	SSP2 -4.5	-4.3	-3.2	1.2	6.8	12.5	18.3	23.2	24.2	19.9	12.8	5.4	-1.1
		SSP3 -7.0	-3.2	-1.9	2.4	7.9	13.5	19.4	24.3	25.5	21.4	14.3	6.7	0.2
		SSP5 -8.5	-1.9	-0.9	3.4	8.8	14.5	20.5	25.3	26.4	22.6	15.5	7.9	1.4

Table S4. Differences in future runoff projections due to hydrological model parameters

(unit: m^3/s)

Basins	SSPs	GCMs	NF					GCMs	DF				
			$Q_{2.5}$	Q_{25}	Q_{50}	Q_{75}	Rank		$Q_{2.5}$	Q_{25}	Q_{50}	Q_{75}	Rank
AD	SSP2-4.5	M5	25.8	10.5	4.7	0.8	1	M3	28.1	7.9	3.5	1.2	1
		M10	27.8	7.8	4.1	1.6	2	M5	23.8	10.5	3.7	1.2	2
		M18	20.5	10.4	3.5	1.0	3	M18	19.7	11.6	4.6	1.7	3
	SSP3-7.0	M6	29.6	10.6	4.6	0.7	1	M5	26.3	13.7	5.3	0.6	1
		M18	18.5	8.4	5.5	2.0	2	M18	27.2	11.8	4.3	1.1	2
		M10	18.1	8.2	4.6	0.7	3	M8	25.0	11.2	4.5	0.6	3
	SSP5-8.5	M1	26.9	7.8	4.7	1.3	1	M10	28.6	8.0	6.5	1.2	1
		M7	24.9	8.6	4.3	1.1	2	M6	22.0	12.1	4.8	1.7	2
		M5	25.0	7.8	4.6	0.9	3	M4	23.8	11.6	4.6	0.9	3

CJ	SSP2-4.5	M5	29.2	18.8	9.0	4.8	1	M16	34.2	9.2	8.9	3.3	1
		M20	26.1	21.4	7.7	2.2	2	M9	19.3	17.1	10.3	1.9	2
		M19	14.5	18.1	6.9	4.4	3	M7	16.2	20.1	7.3	1.7	3
	SSP3-7.0	M13	25.8	18.0	4.7	3.4	1	M18	13.9	20.9	10.5	4.0	1
		M16	29.5	8.7	9.0	3.6	2	M20	17.2	13.7	12.6	4.4	2
		M8	18.1	19.5	8.5	3.5	3	M9	20.0	17.7	8.2	1.5	3
	SSP5-8.5	M5	33.6	14.8	9.0	4.1	1	M2	34.2	11.3	10.2	2.6	1
		M9	32.0	12.9	5.7	1.5	2	M3	35.9	13.6	7.8	1.9	2
		M2	29.0	7.1	9.6	2.9	3	M5	35.4	10.2	9.0	2.9	3
HCH	SSP2-4.5	M16	2.8	1.1	1.5	1.0	1	M4	4.1	1.8	0.9	1.0	1
		M6	2.4	1.0	1.1	1.1	2	M17	3.4	0.9	1.2	0.9	2
		M19	2.8	1.2	0.7	0.9	3	M16	2.2	1.3	1.2	1.0	3
	SSP3-7.0	M6	2.2	2.4	1.0	1.0	1	M7	3.7	1.5	1.0	0.9	1
		M5	3.3	0.6	0.9	1.1	2	M16	2.7	1.2	1.1	1.1	2
		M20	3.0	0.9	1.0	0.6	3	M20	2.7	1.5	0.5	0.8	3
	SSP5-8.5	M13	4.9	1.1	1.4	0.4	1	M6	2.3	1.3	1.4	1.5	1
		M7	2.9	0.9	1.5	1.0	2	M20	3.4	1.2	1.3	0.7	2
		M6	3.1	0.7	1.2	1.0	3	M16	3.0	1.7	0.7	1.3	3
SJ	SSP2-4.5	M5	3.6	1.8	1.3	0.2	1	M18	5.4	1.8	1.2	0.3	1
		M6	3.7	1.6	1.0	0.4	2	M7	3.8	2.2	1.0	0.5	2
		M15	3.4	1.5	1.3	0.4	3	M6	4.5	1.6	1.0	0.5	3
	SSP3-7.0	M4	3.9	2.7	1.2	0.4	1	M7	5.9	1.7	1.0	0.4	1
		M7	4.6	1.6	1.2	0.5	2	M6	4.7	2.7	0.7	0.7	2
		M19	4.1	1.9	1.2	0.5	3	M20	3.2	2.5	1.9	0.2	3
	SSP5-8.5	M20	4.4	1.5	1.1	0.4	1	M16	5.3	1.6	1.3	0.4	1
		M8	4.4	1.2	1.1	0.5	2	M13	3.6	2.2	1.7	0.4	2
		M14	4.9	0.9	1.2	0.2	3	M12	4.4	1.7	1.2	0.6	3

Table S5. Contribution of hydrological model parameters to the uncertainty in prediction of future runoff for each basin

(unit: %)

Name of Basin	NF				DF			
	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
AD	7.54	5.74	4.21	2.42	5.86	3.48	3.54	2.56
CJ	3.24	2.88	1.71	3.90	2.96	2.71	1.68	2.75
HCH	2.20	1.17	4.94	6.09	1.82	0.92	4.43	5.50
SJ	5.58	3.67	3.30	2.30	3.88	2.23	3.34	1.93