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Evaluation of Climate Forecast System Reanalysis weather data driving hydrological model for the Yangtze River basin in China

Jianzhong Lu [1,2], Xiaolin Cui [1], Xiaoling Chen [1], Sabine Sauvage [2], José-Miguel Sánchez-Pérez [2]

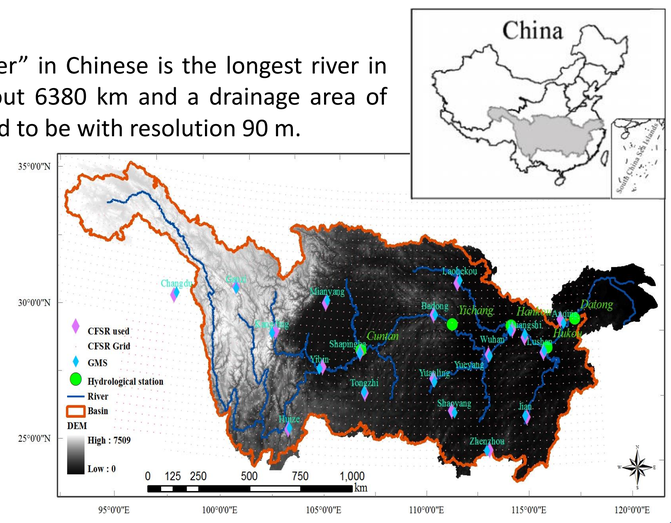
Scientifical Context and objectives

Collecting adequate representative meteorological data has been a problem for watershed modelling mainly in countries where data are difficult to obtain like in China. However, hydrological modelling can benefit from the Climate Forecast System Reanalysis (CFSR) global meteorological dataset. The applicability of global reanalysis climate data for hydrological model predictions in such a great basin: the Yangtze River basin has not so far been adequately investigated. The aim of this study is to assess the applicability (performance) of CFSR weather data used as the input data instead of traditional GMS (Ground-based Meteorological Station) weather data for hydrology prediction in a large-scale watershed.

Study site and data

The Yangtze River, also called Changjiang which means "Long River" in Chinese is the longest river in China, and the third longest in the word, with the length of about 6380 km and a drainage area of 1.8×10^6 km^2. The DEM was derived from the SRTM DEM processed to be with resolution 90 m.

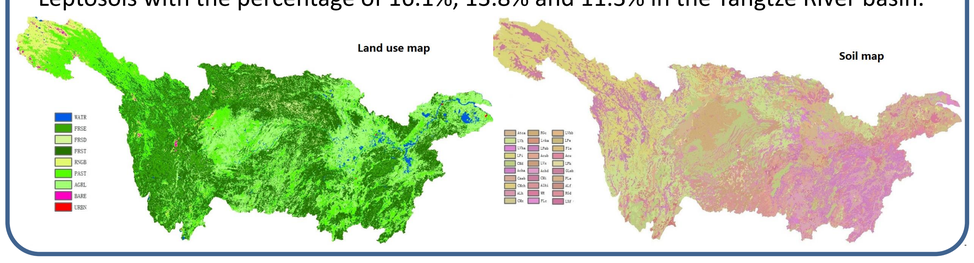
The annual averaged stream flow of Yangtze River is 9.5×10^{11} m^3, and the averaged runoff depth is 526 mm, which is the largest stream flow in China, with 35% stream flow of whole China' rivers. Four mainly hydrological gauge stations (Cuntan, Yichang, Hankou and Datong) were selected to monitor their stream flows. The original hydrological data were collected from the Bureau of Hydrology, Yangtze River Water Resources Commission for China with monthly stream flow. The traditional GMS weather data generally covering the whole Yangtze River basin, the datasets during 1979-2005 were downloaded from China Meteorological Data Sharing Service System.



Methodology

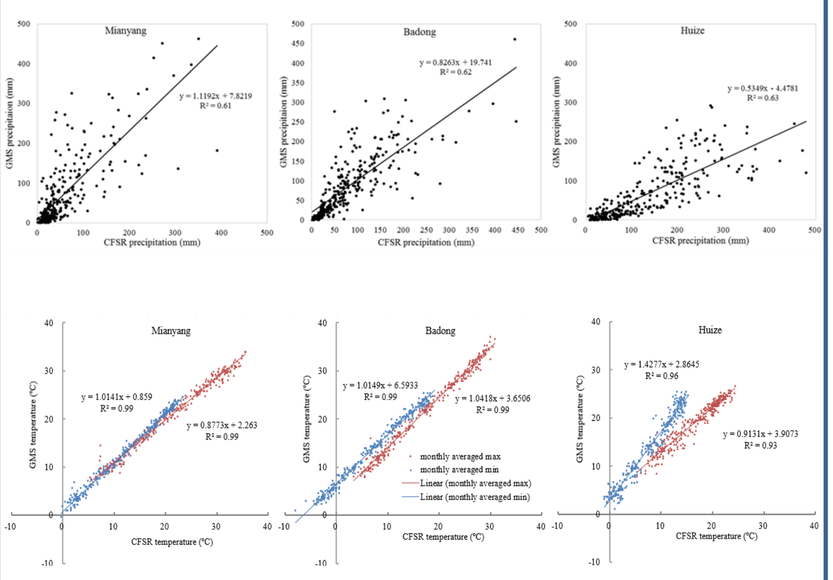
Land use data with 1 km spatial resolution were produced by the Department of Geography University of Maryland (USA). The main land use type is forest accounting to 36% of the area, while pasture 23.5% and crop land 23% in the basin.

The original soil data were produced by the Institute of Soil Science, Chinese Academy of Sciences based on the Second National Soil Survey of China. Soil properties were extracted by 1:1,000,000 Harmonized World Soil Database (HWSD) version 1.1. The main soil type is Haplic Luvisols, Cumulic Anthrosols, and Gelic Leptosols with the percentage of 16.1%, 13.8% and 11.3% in the Yangtze River basin.



Modelling approach

The CFSR grids almost nearby the GMS Huize, Mianyang and Badong meteorological stations were selected to compare monthly precipitation and temperature between both kinds of datasets during 1981-2005 (n=300).

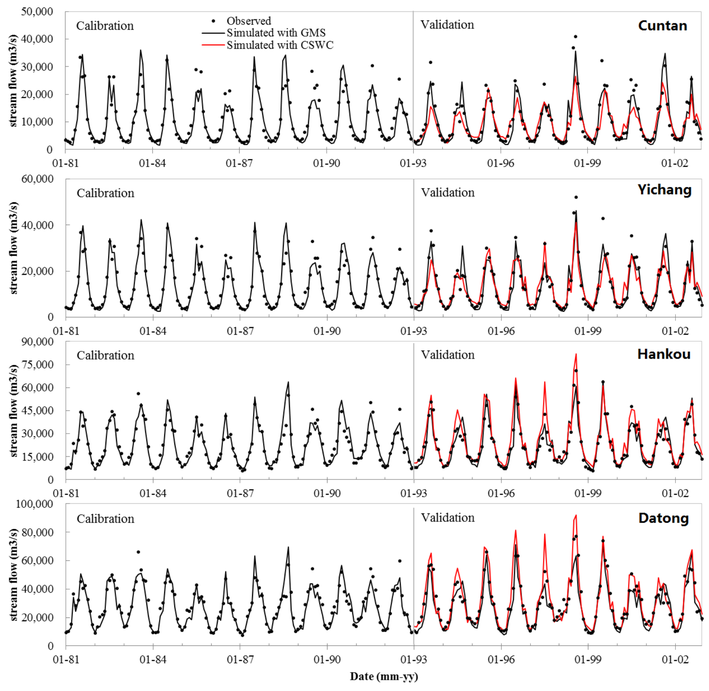


The Yangtze River basin was firstly divided into 22 subbasins based on input DEM, and then divided into 422 HRUs according to the land use, soil types and slope characteristics in the watershed. The meteorological data for 19 even-distributed GMS stations in the basin were used in the model, and the same number of CFSR grids nearby the GMS stations were selected.

Results : Calibration and Validation

Calibration and validation of SWAT model driven by GMS weather data

Parameter sensitivity analysis and calibration were conducted based on GMS data driving SWAT model in comparison of stream flow for each hydrological gauge station during 1981-1992, and simulated results were validated by observed data during 1993-2002. The calibrated parameters in GMS simulation were then applied in the CFSR driving SWAT model without parameter calibration (CSWC).



	Calibration			Validation			Validation with CSWC		
	R^2	E_{NS}	PBias/%	R^2	E_{NS}	PBias/%	R^2	E_{NS}	PBias/%
Cuntan	0.86	0.85	5.34	0.83	0.82	5.85	0.78	0.71	11.22
Yichang	0.90	0.89	2.74	0,87	0.87	3.91	0.85	0.83	1.43
Hankou	0.88	0.87	0.59	0.87	0.86	2.81	0.89	0.82	-12.01
Datong	0.86	0.85	4.07	0.84	0.81	9.88	0.88	0.81	-5.82

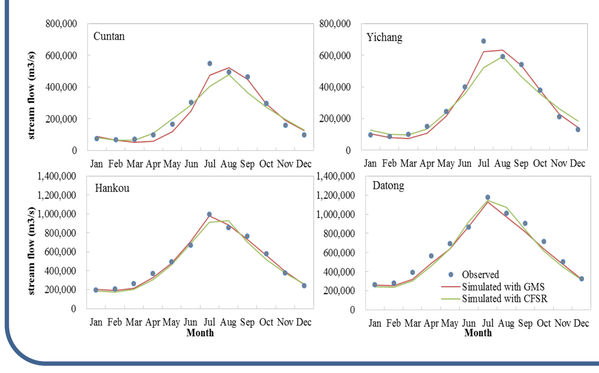
The validation of CSWC presents acceptably results generated by CFSR driving model with the parameters calibrated in GMS data driving SWAT model. The CFSR and GMS weather data driving SWAT model sometimes can share the same group of hydrological parameters for hydrology prediction in Yangtze River basin.

We calibrated parameters for each simulation of different hydrological stations. For each simulation driven by GMS and CFSR weather data at different hydrological gauge station, parameter sensitivity analysis and parameter calibration were conducted.

Parameters	GMS weather data				CFSR weather data			
	Cuntan	Yichang	Hankou	Datong	Cuntan	Yichang	Hankou	Datong
CN2	1.92	1.85	1.25	1.38	1.81	0.77	1.10	1.26
CH_K2	10.12	4.02	4.67	6.52	15.91	0.55	1.50	4.20
ESCO	0.95	0.85	0.85	0.96	0.85	0.15	0.15	0.85
CANMX	—	—	—	—	1.08	6.47	8.50	4.20
RCHRG_DP	0.26	0.54	0.35	0.38	0.25	0.15	0.45	0.16
ALPHA_BF	0.03	0.048	0.006	0.016	—	—	—	—

Results

CFSR model	Calibration			Validation		
	R^2	E_{NS}	PBias/%	R^2	E_{NS}	PBias/%
Cuntan	0.82	0.82	0.51	0.78	0.70	14.73
Yichang	0.85	0.85	-3.27	0.78	0.68	15.52
Hankou	0.87	0.83	-2.89	0.91	0.84	14.62
Datong	0.87	0.81	-2.68	0.91	0.82	15.82

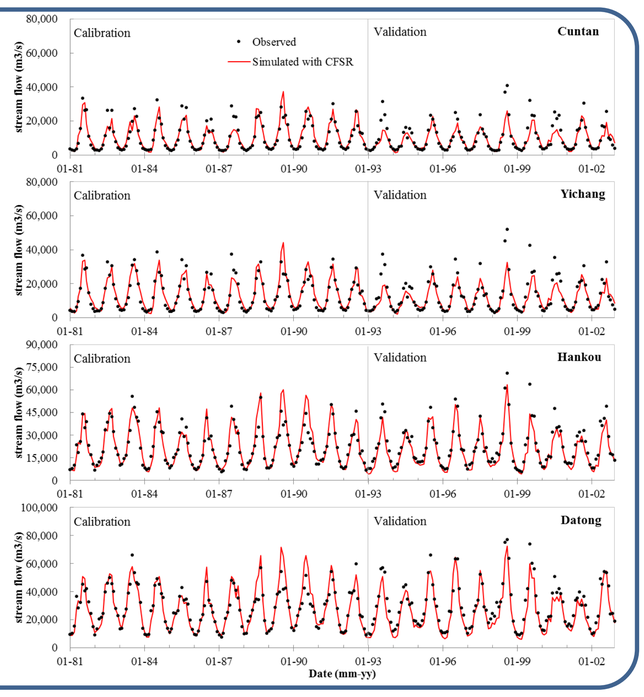


Calibration and validation of SWAT model driven by CFSR weather data

The CFSR driving SWAT model without parameter calibration (CSWC) has presented its sophistication. However, this sufficiency of modelling performance closely depended on the parameters calibrated with GMS weather data. In the CFSR driving model, the R^2 of precipitation validation is only about 0.6 between CFSR and GMS weather data, the SWAT model produced the stream flow with larger R^2 and E_{NS}. The established SWAT model provides parameter adjustment to improve the accuracy of hydrology prediction through parameter sensitivity analysis and model calibration. Although, it seem that the stream flow simulated with GMS weather data is much better than that simulated with CFSR weather data, the results simulated with CFSR weather data in fact are reasonably accepted.

Comparison of monthly averaged stream flow among the observed data, simulated results with SFSR and GMS weather data

Hydrographs with the long-term average monthly stream flow during the year 1981 to 2002 were used to compare the performance of GMS and CFSR weather data simulations. Comparing the average monthly stream flow hydrograph, Results from GMS and CFSR simulations will be characterized with two different patterns in upper, middle and lower reaches. Totally speaking, CFSR weather simulation generated better results in the middle and lower reaches than that in the upper reach of Yangtze River basin.



Conclusions

(1) The study demonstrated that the CFSR globe weather data were with reasonable accuracy to represent the weather condition occurring in the Yangtze River basin at large scale. (2) The CFSR and GMS weather data driving SWAT model can share the same group of hydrological parameters for hydrology prediction in Yangtze River basin. (3) The CFSR weather data driving hydrological model provides stream flow simulations that are as good as or better than models driven by traditional GMS weather data, and CFSR weather simulation generated better results in the middle and lower reaches than that in the upper reach of the Yangtze River basin. The CFSR globe data provide a good data source for quickly establishing SWAT model for hydrology prediction.

[1] State key Laboratory of Information Engineering in Surveying, Mapping and Remote Sensing (LIESMARS), Wuhan University, Wuhan 430079, China
[2] University of Toulouse; INPT, UPS; CNRS ;
Laboratoire Ecologie Fonctionnelle et Environnement (EcoLab), France