An evaluation of the performance of statistical downscaling method in driving hydrological model

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1. Introduction

Studies of climate change impacts on water resources have been hot topics among hydrologists and meteorologists currently. These studies are commonly done in three steps: (i) simulations of large scale climate scenarios by one or a group of general circulation models (GCMs), (ii) downscaling of large scale climate scenarios into regional by using downscaling techniques, and (iii) the resulting regional scale climate data are used to run a selected hydrological model to simulate runoff for a selected catchment or region. This study deals with steps (ii) and (iii) .

The study is performed in Hanjiang basin in China. The NCEP/NCAR global reanalysis data are used to calibrate and validate the statistical downscaling techniques, i.e. SSVM and SDSM. The A2 scenario from CGCM3 and A2 and B2 scenarios from HadCM3 are selected as background of large-scale climate, which are used as the input to the Xin-anjiang and HBV hydrological models. Then the simulated runoffs corresponding to various combinations of scenarios, GCMs, downscaling methods, and hydrological models are comprehensively analyzed. The technique route of this study was drawn in Fig. 1

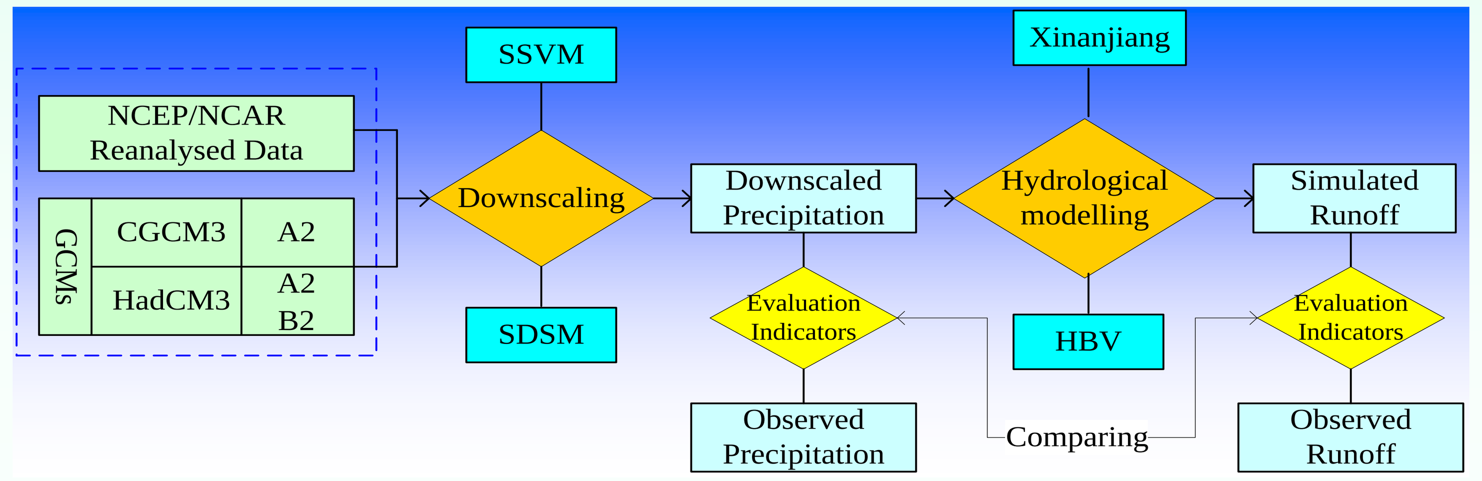

Fig.1 The technique route of this study

2. Study area and Data

a). Study area

The upper Hanjiang River is selected as the study area which has an area of 59115 km^2 (Fig.1)

b). Data

The NCEP/NCAR reanalysis daily data are used as the observed large-scale climate data to calibrate and validate the downscaling models. The daily air temperature, rainfall, pan evaporation data of 7 stations and the runoff data of Baihe Station from 1961 to 2000 are used for calibration and validation of the hydrological models. The A2 scenario from the CGCM3 and A2 and B2 scenarios from the HadCM3 are used to produce regional climate scenarios, which in turn are used to simulate hydrological responses.

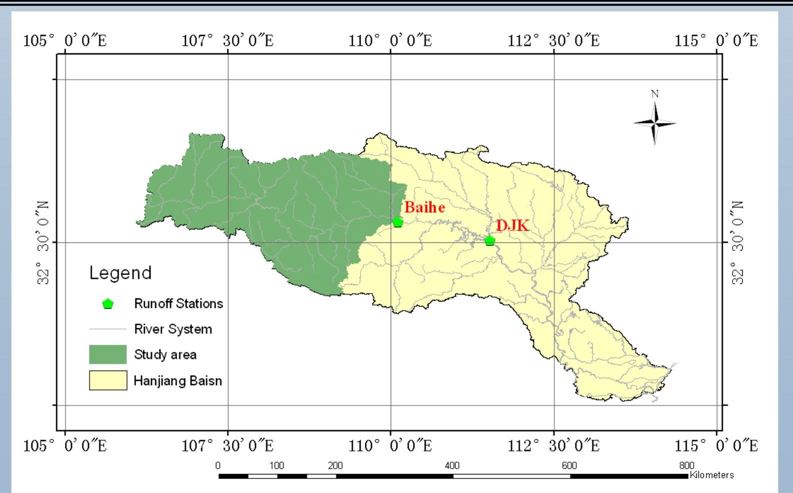

Fig.2 The location of the study area

3. Methods

a). Statistical Downscaling Methods (SD)

This study uses two typical SD methods: Smooth Support Vector Machine (SSVM) (Chen et al., 2010) and Statistical Downscaling model (SDSM) (Wilby et al., 2002).

b). Hydrological Models

To investigate the difference between different hydrological models for climate impact study, the Xin-anjiang model (Zhao, 1992) and HBV model (Bergstrom, 1975) are used.

4. Results and Discussion

4.1 Comparison of SSVM and SDSM Fig. 3 shows the monthly precipitation simulated by SSVM and SDSM from NCEP data. Other statistic indicators for comparison the performance of SSVM and SDSM are given in Table 1. The results show that most of the traditional statistical indicators indicate that SDSM performed better than SSVM in the study region.

4.2 Verification of hydrological models The ability and difference of the two hydrological models in simulation of historical discharge data are compared in Fig.4 and Table 2. It is seen that the two models perform equally well in reproducing the historical flow record.

4.3 An analysis of precipitation simulation through different GCMs and scenarios Fig.5 shows the differences between CGCM3 and HadCM3 by utilizing the same downscaling method and emission scenario. It could be seen that most monthly precipitation statistics from CGCM3 agreed better to the observed than that from HadCM3 in this region. Fig. 6 shows that the means are well produced using both scenarios, while both scenarios under estimate the standard deviation and 5-day maximum rainfall.

4.4 An analysis of runoff simulation through different GCMs, scenarios, statistical downscaling methods and hydrological models. Table 3 shows the runoff simulation results of different precipitation scenarios. It is evident that the error of runoff simulation by using the precipitation inputs obtained through SDSM is significantly greater than that of SSVM. For the NCEP reanalysis data, the NEC (13.89%) by SDSM was significantly lower than that of SSVM, which is 71.01%. The performance of runoff simulation from CGCM3 is better than that from HadCM3, which shows that CGCM3 is more appropriate for studying the climate change impact than HadCM3 in this basin. There is little difference to the simulated runoff by A2 and B2 scenarios combined with SSVM.

Table1 Indicators comparison of precipitation simulation

Indicators	P_Observed	P_SSVM_NCEP	P_SDSM_NCEP
Percentage wet	0. 38	0. 58	0. 41*
Mean dry spell length	4. 31	2. 61	2. 93*
Mean wet spell length	2. 66	3. 67	2. 04*
SD dry spell length	2. 40	4. 50	1. 78*
SD wet spell length	5. 26	2. 70	4. 19*
POT as % of total	0. 41	0. 38	0. 42*
MeanDry-daypersistence	0. 93	0. 82	0. 85*
MeanWet-daypersistence	0. 85	0. 90*	0. 73
Nash coefficiency	–	52. 38*	−77. 41
Total precipitation error	–	1. 05	0. 97*

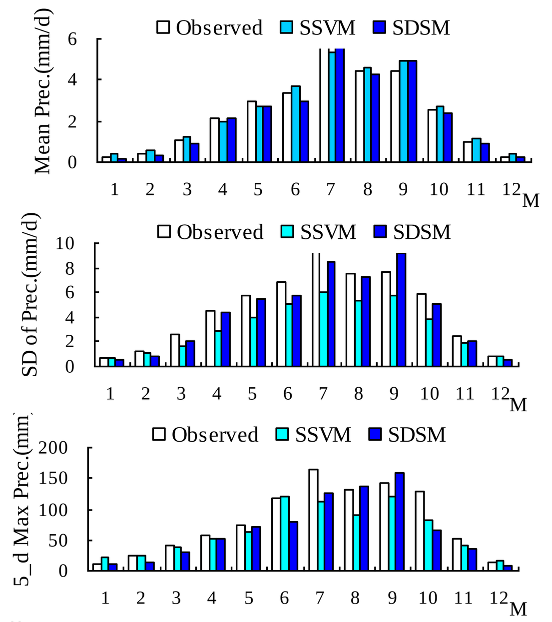

Fig. 3 The monthly precipitation comparison downscaled from NCEP/NCAR data using SSVM and SDSM

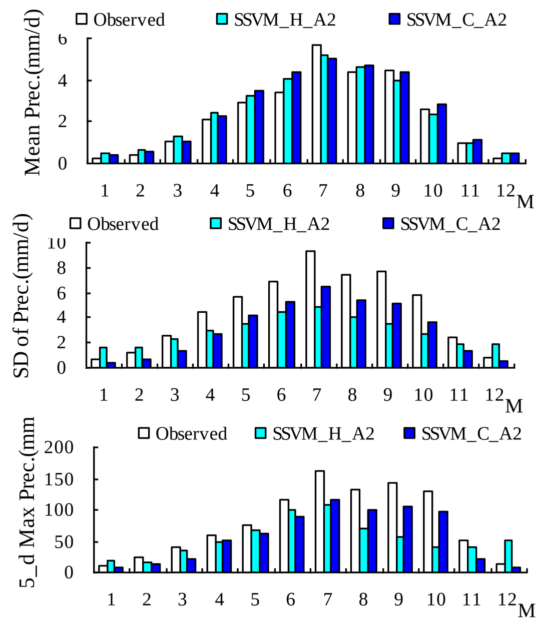

Fig. 5 the comparison monthly precipitation downscaled from CGCM3 and HadCM3 in same A2 scenario

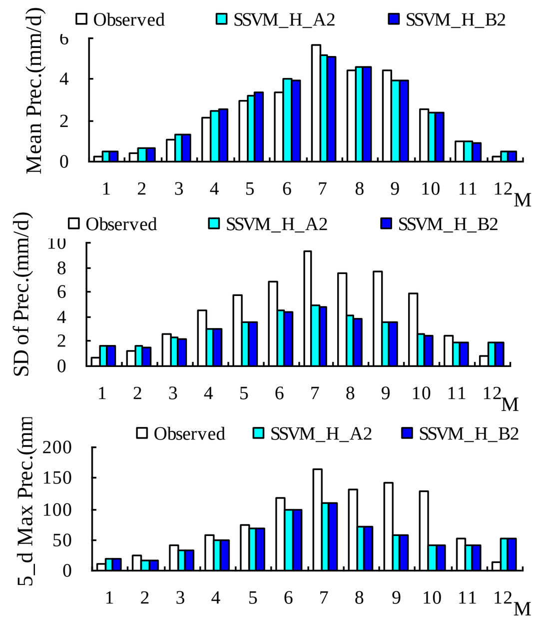

Fig. 6 the comparison monthly precipitation downscaled from A2 and B2 scenarios of the HadCM3

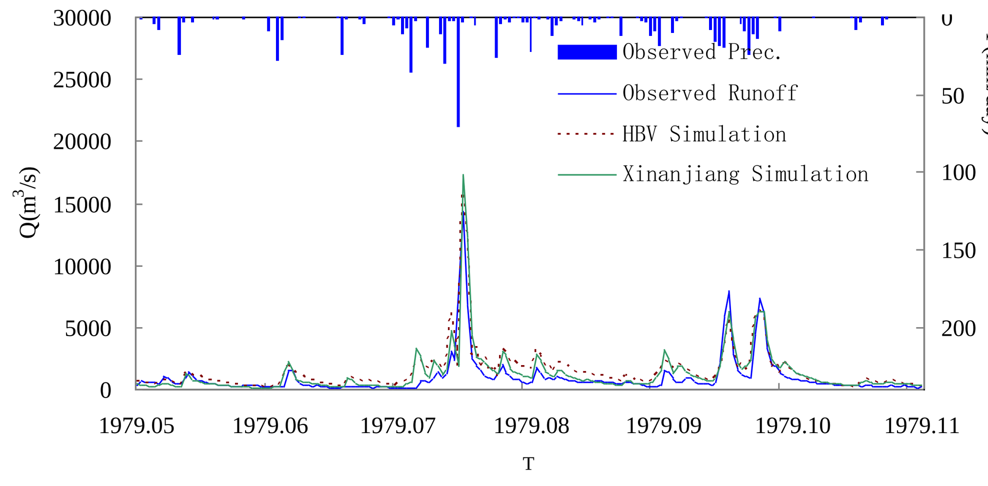

Fig. 4 Observed and simulated discharge hydrograph

Table2 Evaluation of hydrological models parameters

Hydrological Model	Calibration		Evaluation	
	WBC (%)	NEC (%)	WBC (%)	NEC (%)
HBV	0	85.91	2.84	85.72
Xinanjiang	0	84.58	0.27	85.38

Note:
WBC: the water balance coefficient ;
NEC: the Nash-Sutcliffe efficiency coefficient

Table 3 Runoff simulation results of different precipitation scenarios

Prec. Scenarios \ Hydrological models	Xinanjiang NEC (%)	HBV NEC (%)
P_Observed	87.34	84.55
P_SDSM-NCEP	13.89	9.58
P_SDSM-CGCM3-A2	25.30	16.45
P_SDSM-HadCM3-A2	2.27	1.29
P_SDSM-HadCM3-B2	10.72	6.41
P_SSVM-NCEP	71.01	70.53
P_SSVM-CGCM3-A2	61.57	50.93
P_SSVM-HadCM3-A2	56.94	39.96
P_SSVM-HadCM3-B2	56.65	39.86

4.5 Discussion Table 1 and Fig.3 show that most statistical indicators (except perhaps NEC) used in evaluation of the performance of downscaling methods reveal that SDSM performed better than SSVM. However, Table 3 shows that the NEC of runoff simulation by using the precipitation downscaled from SDSM is much lower than that of SSVM. This study clearly show that most of the indicators used in this study and in the literature for evaluation of downscaling methods cannot fulfill the need of hydrological modeling study. Future study needs to define and verify more useful indicators for evaluation of downscaling methods in order to determine the best downscaling method for providing most useful precipitation data as input to drive hydrological models.

5. Conclusions

(1) The Xin-anjiang model and HBV model have similar performance in simulation of historical streamflow in the catchment.
(2) For the same climate scenario, downscaling technique and hydrological model, the results showed that CGCM3 is more suitable than HadCM3 to investigate the climate change impact on runoff in this region. The differences in simulation result of runoff resulted from using A2 and B2 emission scenarios are small.
(3) Most statistical indictors used in this study as well as in the literature for evaluation of the performance of downscaling methods show SDSM has better performance than SSVM in downscaling precipitation, except Nash-Sutcliffe coefficient used to compare the downscaled and observed precipitation reveals that SSVM performed better than SDSM.
(4) For the same GCM, climate scenario and hydrological, the simulation results of runoff vary greatly with the choice of downscaling methods for producing regional climate scenario as input to hydrological models; SSVM performed better than SDSM in studying climate change impact on the runoff in the Hanjiang basin.
(5) Combining points (3) and (4) we can conclude that among the indicators used for the assessment of statistical downscaling methods, the Nash-Sutcliffe efficiency is a more useful indicator than others as far as the simulated discharge is used as an evaluation criterion. More useful indicators than what are reported in the literature and showed in Table 2 for evaluation of downscaling methods need to be defined and evaluated in order to determine the best downscaling method for providing most useful precipitation data as input to drive hydrological models.

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