WeeklyNote

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Finding appropriate bias correction methods in downscaling precipitation for hydrologic impact studies over North America

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Introduction

在山区地区，由于降水以及温度变量依赖高度的特性无法由GCM表现出来，高精度的信息经常需要和粗糙的GCM进行合并。

特别的，由于难以模拟对流型降水，相较于秋季和冬季，RCM对于降水的精度在夏季最差。

因此，本文使用6中方法，对四个原始RCM的最高温、最低温以及降水量进行统计降尺度并进行比较。

Method

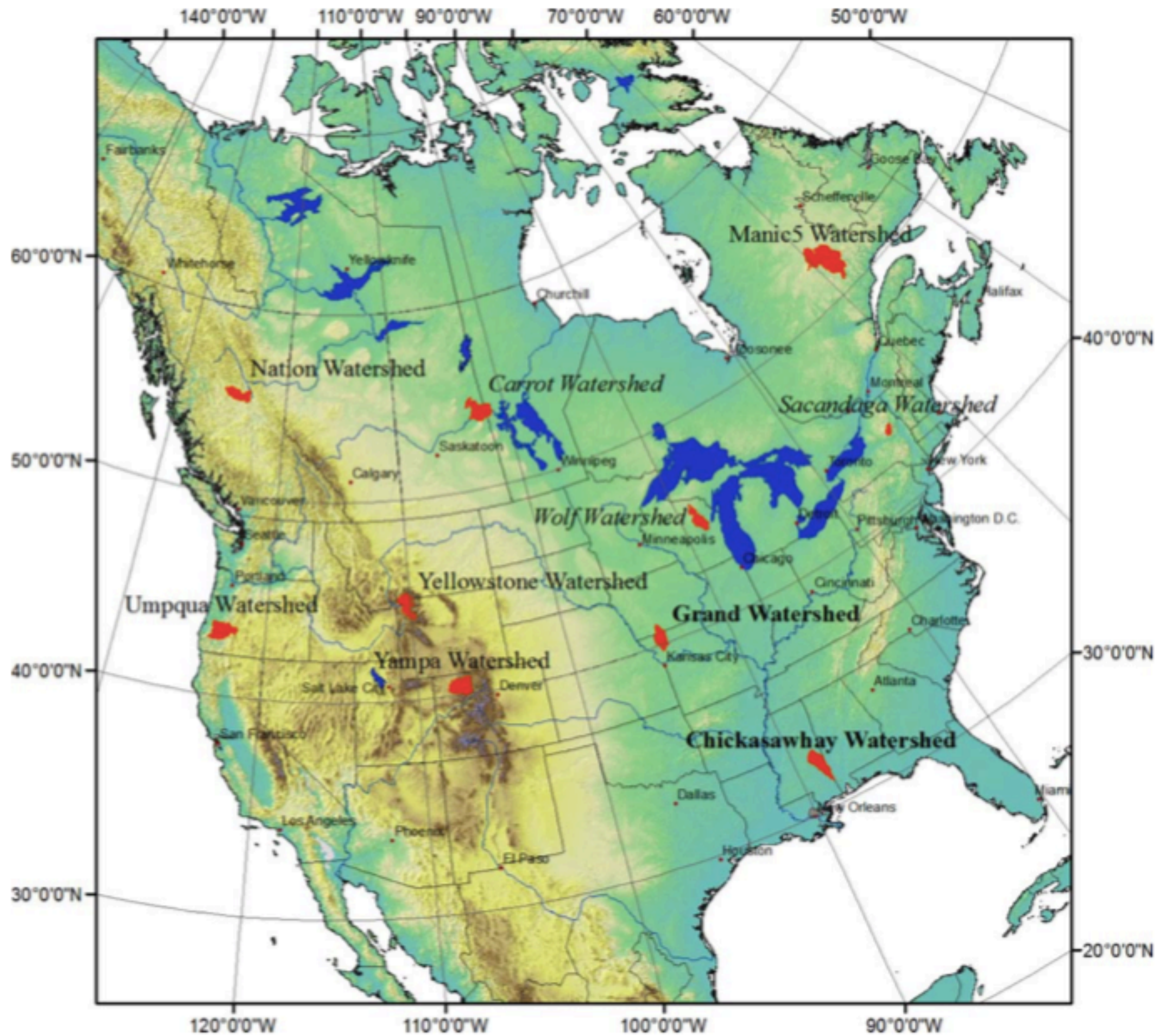

Figure 1. Location of the 10 selected river basins over North America. Different typefaces on watershed name represent different performances of bias correction approaches for hydrological modeling: roman = good, italic = bad, and bold = very bad.

Method

Table 1. Basic Information of the Selected 10 River Basins Over North America and the Nash-Sutcliffe Coefficient (NSE) of the Calibration and Validation of Hydrological Model HSAMI[a]

Country	Province or State	Basin Name	Area (km^2)	Precip (mm)	Tmax (°C)	Tmin (°C)	Calibration Period	NSE Calibration	Validation Period	NSE Validation
Canada	BC	Nation	6790	612	5.9	−4.3	1981–1993	0.932	1994–2003	0.905
	SK	Carrot	12,600	409	6.1	−5.4	1967–1980	0.822	1981–2000	0.719
	QC	Manic 5	24,610	902	2.5	−7.9	1966–1980	0.917	1981–2000	0.856
USA	OR	Umpqua	9535	1270	16.7	4.4	1948–1980	0.907	1981–2000	0.889
	MT	Yellowstone	6791	688	8.5	−5.3	1948–1980	0.897	1981–2000	0.701
	CO	Yampa	8828	598	12.5	−3.4	1948–1980	0.815	1981–2000	0.728
	MO	Grand	5825	872	16.9	4.9	1948–1980	0.754	1981–2000	0.778
	WI	Wolf	5851	769	12.0	0.7	1948–1980	0.847	1981–2000	0.744
	MS	Chickasawhay	6967	1428	24.7	11.1	1948–1980	0.861	1981–2000	0.851
	NY	Sacandaga	1271	1215	11.7	−0.5	1948–1980	0.798	1981–2000	0.807

[a]Precip = precipitation, Tmax = maximum temperature, and Tmin = minimum temperature.

1. 10个盆地覆盖了北美地区5中气候区域（基于Koppen天气划分法）；
2. 这10个盆地同样通过不同的地形条件进行了挑选（从西部的多山地形到中部和东部的平原地区）；
3. 位于加拿大的3种盆地坐落于Quebec, Saskatchewan和British Columbia三个地区，尽管它们都是降雪覆盖型盆地，但它们同样具有不同的气候条件。

Method

Data set：

1. 观测得到的日降水，日最高温和日最低温以及RCM模拟得到的日降水;
2. 位于加拿大的3种盆地的数据取自National Land and Water Information Service(www.agr.gc.ca/nlwis-snite) data set;
3. 四个由NCEP在北美地区根据再分析资料驱动的RCMs（Canadian Regional Climate Model (CRCM), Hadley Regional Model 3 (HRM3), Regional Climate Model version 3 (RCM3), and Weather Research & Forecasting model (WRFG)）;
4. Spatial resolution: 50km;
5. Period: 1981-2000.

Method

mean-based approaches

distribution-based approaches

Table 2. The Advantages (or Characteristics) and Disadvantages of the Six Bias Correction Methods

Method	Advantage	Disadvantage	Reference
1. Linear scaling (LS)	*Mean-based*	The daily precipitation sequence is the same as that of the RCM-simulated data (usually too many wet days compared to the observation).	*Lenderink et al.* [2007] and *Teutschbein and Seibert* [2012]
	A mean monthly correction factor is applied to the RCM-simulated daily precipitation in a month. It is the simplest bias correction method.	It does not account for the changes in the frequency distribution of precipitation.	
		No adjustment is made to the temporal structure of daily precipitation occurrence.	
2. Local intensity scaling (LOCI)	*Mean-based*	It does not account for the different changes in the frequency distribution of precipitation.	*Schmidli et al.* [2006]
	The wet-day frequency is corrected. A mean monthly correction factor is applied to the RCM-simulated daily precipitation in a month.	No adjustment is made to the temporal structure of daily precipitation occurrence.	
3. Daily translation (DT)	*Distribution-based*	The daily precipitation sequence is the same as that of the RCM-simulated data (usually too many wet days compared to the observation).	*Mpelasoka and Chiew* [2009]
	Different correction factors (differences in percentiles between observed and RCM-simulated data at the calibration period) are applied to correct the frequency distribution of RCM-simulated daily precipitation.	No adjustment is made to the temporal structure of daily precipitation occurrence.	
4. Daily bias correction (DBC)	*Distribution-based*	No adjustment is made to the temporal structure of daily precipitation occurrence.	*Schmidli et al.* [2006] and *Mpelasoka and Chiew* [2009]
	Combines the DT and LOCI approaches to take into account the different changes in frequency distributions of daily precipitation, and corrects the wet-day frequency of precipitation.		
5. Quantile mapping based on an empirical distribution (QME)	*Distribution-based*	No adjustment is made to the temporal structure of daily precipitation occurrence.	*Themeßl et al.* [2010, 2011]
	Corrects the RCM-simulated precipitation based on point-wise daily constructed empirical cumulative distribution functions (ecdfs). The frequency of precipitation occurrence is corrected at the same time.		
6. Quantile mapping based on a gamma distribution (QMG)	*Distribution-based*	The performance depends on whether the observed and RCM-simulated precipitation follows the gamma distribution (or not).	*Ines and Hanson* [2006], *Piani et al.* [2010], and *Teutschbein and Seibert* [2012]
	Corrects the RCM-simulated precipitation based on a gamma distribution. The frequency of precipitation occurrence is corrected using the LOCI method.	No adjustment is made to the temporal structure of daily precipitation occurrence.	

Method

Evaluation of bias correction methods is based on a split-sample cross-validation approach：

1. 1981-2000(20yr)的冠词和RCM降水模拟值分为两部分——10年的基数年和10年的偶数年；
2. 10年的偶数年被用作训练，10年的基数年被用作测试;
3. 10年的基数年被用作训练，10年的偶数年被用作测试；
4. 1981-2000(20yr)全部被用作测试集。

Results

1. 和观测降水数据比较，原始的RCM平均值偏差较大，特别是HRM3和WRFG；
2. LS和DT方法对于降水并未表现出较好的提高；
3. 其他四种方法的确对于降水平均值的偏差的纠正有所改进。

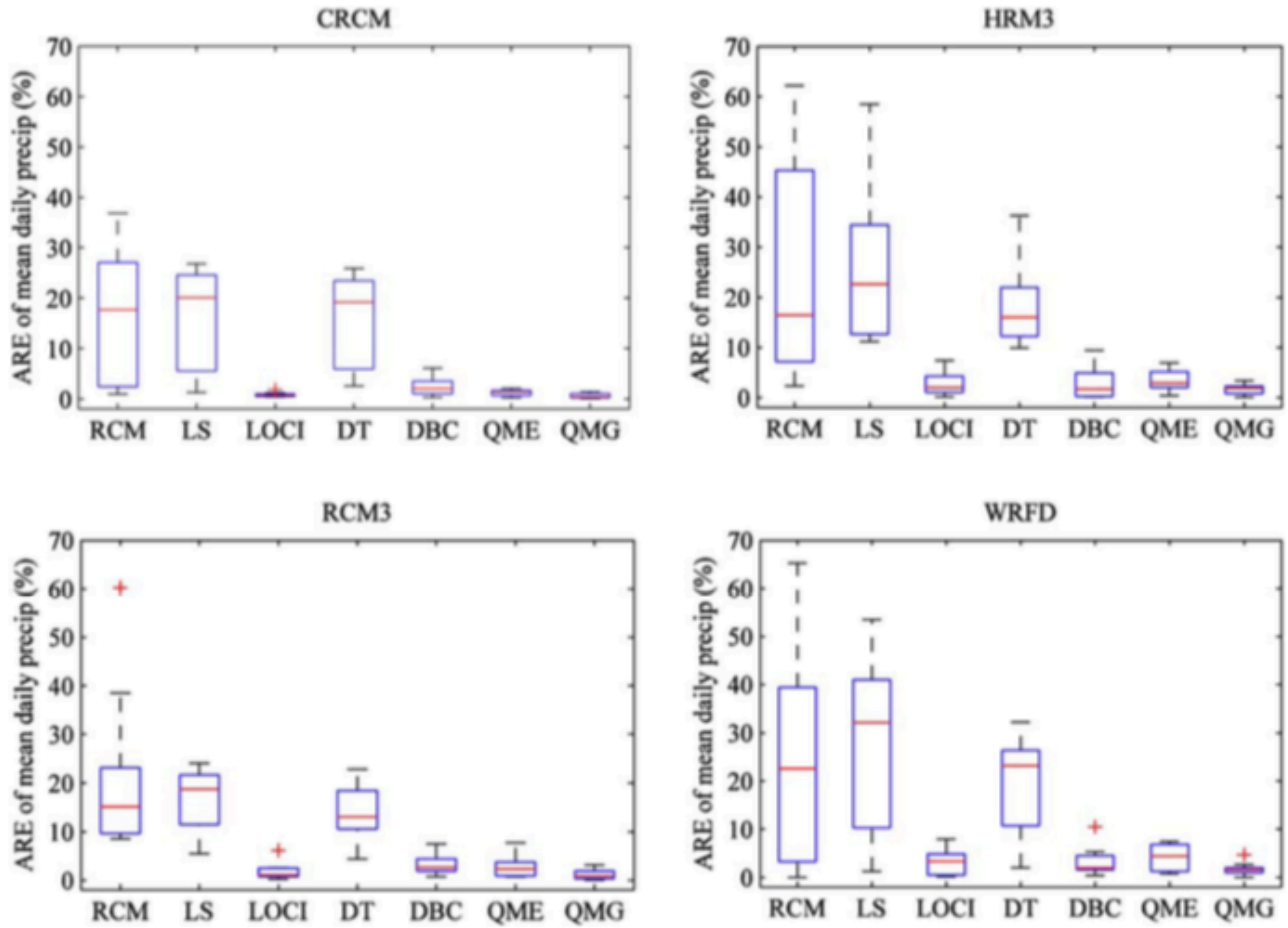

Figure 3. Boxplot of the absolute relative error (ARE) of raw RCM-simulated (RCM) and six bias correction method-corrected daily mean precipitation (precip) values for all four RCMs. Each boxplot is constructed using 10 mean values from 10 river basins.

ARE：0.7%-3.4%(LOCI)，1.7%-2.6%(DBC)，1.2%-4.4%(QME)以0.4%-2.0%(QMG)

Results

1. 和观测降水数据比较，原始的RCM标准差偏差较大；
2. 所有方法均对CRCM的标准差偏差校正有效果；
3. 然而，对于其他三种RCMs，LS和LOCI方法并为是标准差的偏差有所降低。

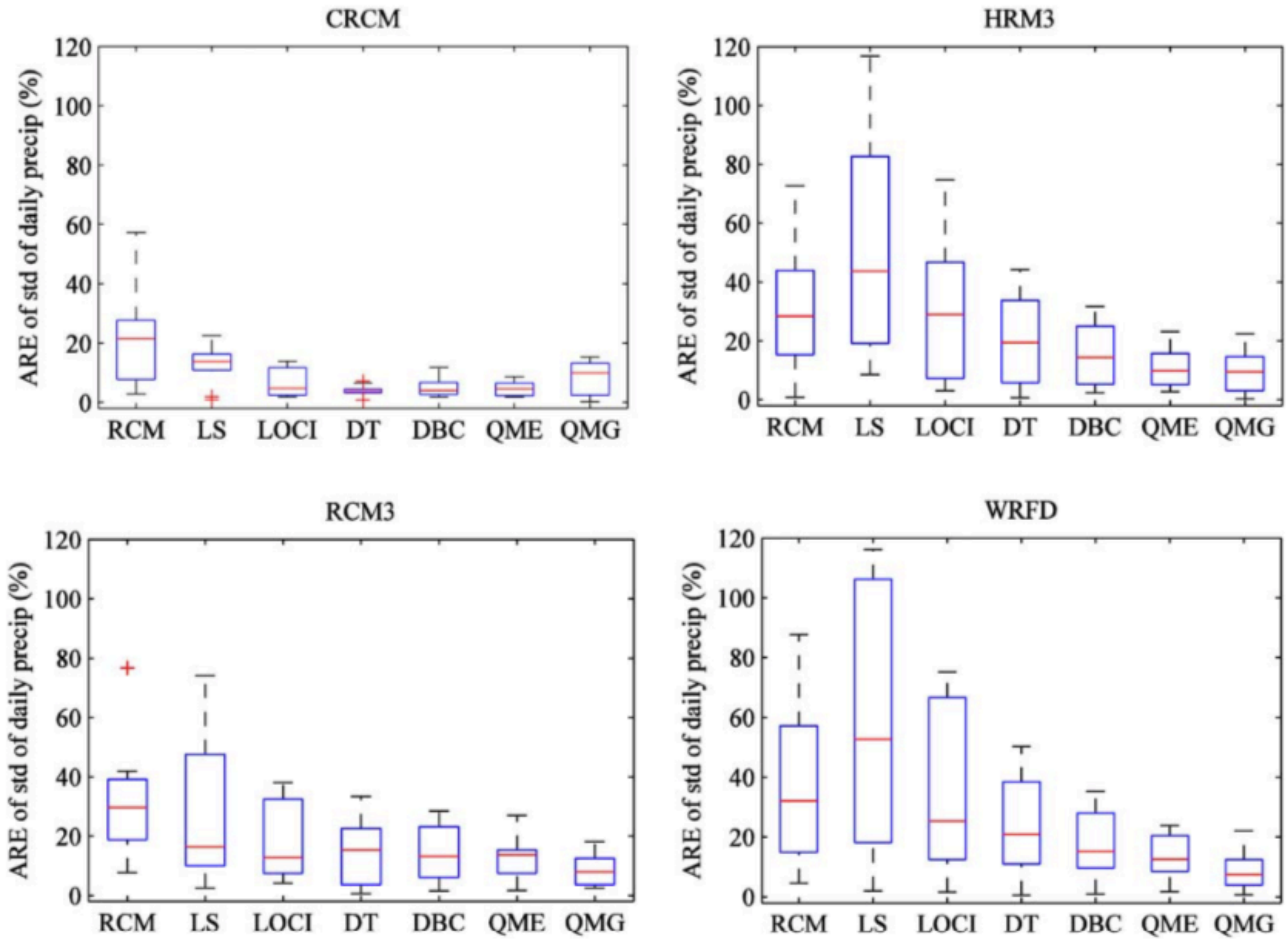

Figure 4. Boxplot of the ARE of standard deviation (std) of raw RCM-simulated (RCM) and six bias correction method-corrected daily precipitation (precip) values for all four RCMs. Each boxplot is constructed using 10 standard values from 10 river basins.

Results

Table 3. Nash-Sutcliffe Coefficient (NSE) of the Calibration (CAL) and Validation (VAL) of Hydrological Model HSAMI Using RCM-Simulated Precipitation Combining With Observed Temperature (Odd Year for Calibration and Even Year for Validation)[a]

Model	Source	Nation	*Carrot*	Manic5	Umpqua	Yellowstone	Yampa	**Grand**	*Wolf*	**Chickasawhay**	*Sacandaga*	Mean
CRCM	CAL	0.84	*0.58*	0.86	0.75	0.92	0.85	**0.27**	*0.48*	**0.39**	*0.54*	0.65
	VAL	0.85	*0.37*	0.77	0.70	0.78	0.73	**−0.11**	*0.46*	**0.33**	*0.18*	0.51
HRM3	CAL	0.91	*0.73*	0.78	0.64	0.88	0.72	**0.07**	*0.28*	**0.29**	*0.39*	0.57
	VAL	0.89	*−0.95*	0.76	0.61	0.79	0.41	**0.06**	*0.30*	**0.00**	*0.34*	0.32
RCM3	CAL	0.81	*0.38*	0.78	0.55	0.89	0.80	**0.09**	*0.24*	**−0.07**	*0.51*	0.50
	VAL	0.81	*0.18*	0.76	0.58	0.75	0.68	**0.02**	*0.23*	**−0.14**	*0.31*	0.42
WRFG	CAL	0.79	*0.34*	0.69	0.61	0.87	0.77	**0.04**	*0.26*	**0.22**	*0.47*	0.51
	VAL	0.86	*0.06*	0.73	0.39	0.78	0.73	**0.03**	*0.05*	**0.14**	*0.35*	0.41
Mean		0.84	*0.21*	0.77	0.60	0.83	0.71	**0.06**	*0.29*	**0.15**	*0.39*	

[a]Different typefaces on watershed name represent different performances of bias correction approaches for hydrological modeling: roman = good, italic = bad, and bold = very bad.

10个偶数年作为训练集，10个基数年作为验证集；

Results

1. 总体而言，原始RCM模拟的降水无法重现大多数流域的观测结果；
2. 但是，除Nation和Carrot，雪山覆盖型盆地的结果通常比无雪覆盖型盆地效果好；
3. 然而，Nation和Carrot的峰值被远远高估。

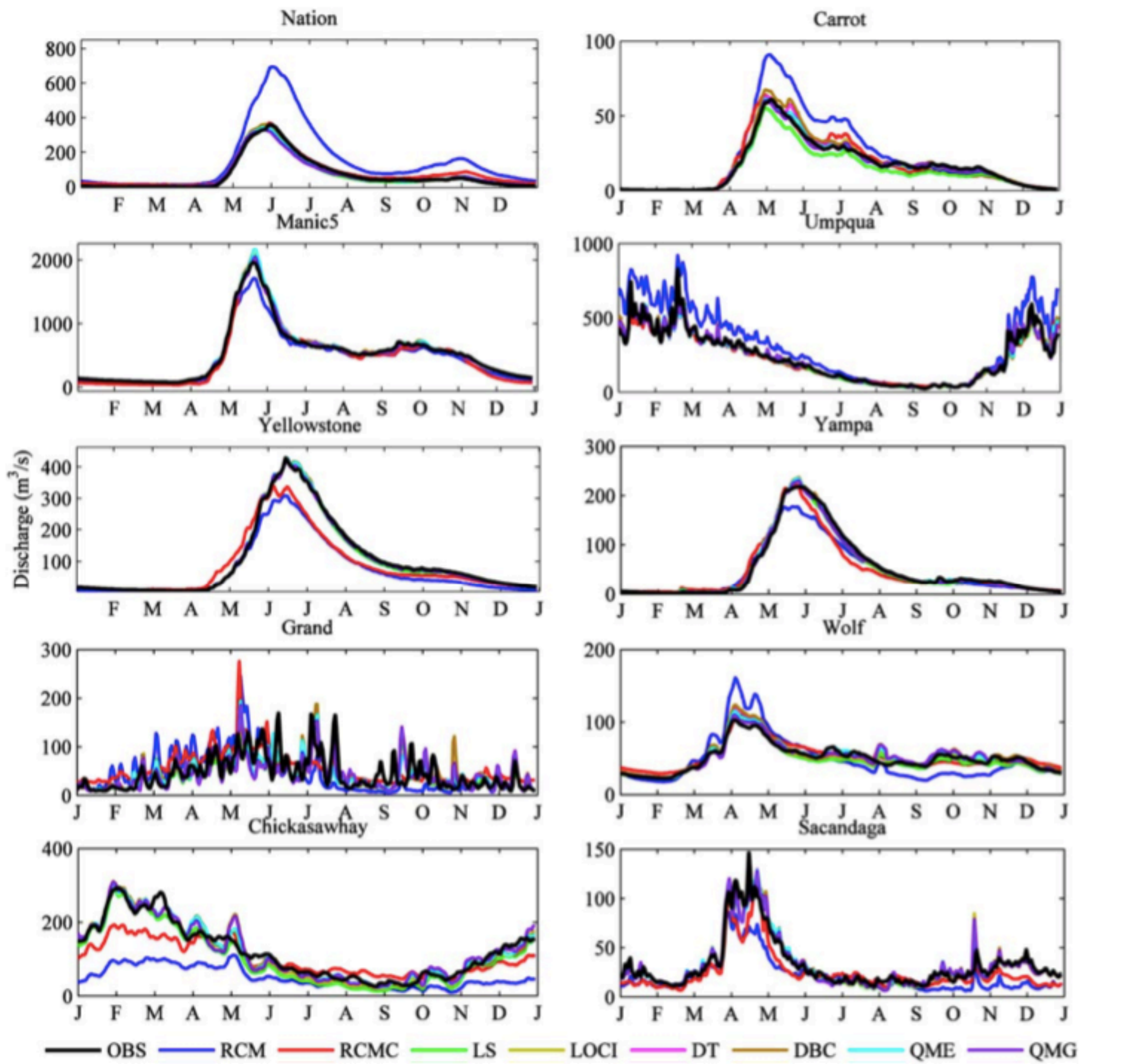

Figure 6. Mean annual hydrographs simulated using observed (OBS), raw RCM-simulated (RCM), and six bias correction methods' corrected precipitation time series from the CRCM simulation for all 10 river basins. The simulated hydrograph using RCM-simulated precipitation (RCMC) but with the specific hydrological model calibration is also plotted.

Conclusions

本文评估了六种偏差较种方法对北美地区10个盆地流域的降水的再现能力:

1. RCM模拟的日降水总是有偏差的，有时甚至偏差较大，因此无法用于水文研究，对RCM进行校正可以改善其模拟，克服部分偏差;
2. 所有的偏差校正方法都对RCM模拟的降水有所改进;
3. 其中，基于分布的方法的效果总是优于基于均值的方法。

谢谢