2019年11月29日

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。

Methods：

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个盆地还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。

Evaluation of bias correction methods is based on a split-sample cross-validation approach：
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；
10年的偶数年被用作训练，10年的基数年被用作测试;
10年的基数年被用作训练，10年的偶数年被用作测试；
1981-2000(20yr)全部被用作测试集。

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

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

Results：

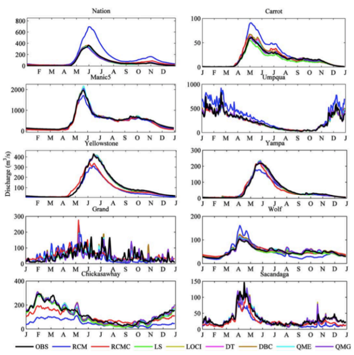

Figure 6. Mean annual hydrographs simulated using observed (OBS), raw RCM-simulated (RCM), and six bias correction methods' corrected precipitation time series from the CRCM simulation for all 10 river basins. The simulated hydrograph using RCM-simulated precipitation (RCMC) but with the specific hydrological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

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.

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:
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;
所有的偏差校正方法都对RCM模拟的降水有所改进;
其中，基于分布的方法的效果总是优于基于均值的方法。