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Statistical downscaling of general circulation model outputs to precipitation – part 1: calibration and validation

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Results

1. 地表降水速率被认为是研究降水的最具代表的变量（列表中除7月不包含，其余月份均包含）；
2. 湿度变量（相对湿度和比湿）是大气水汽的代表性变量（12个月中有7个月均包含[February, March, May, September, October, November, December]）；
3. 在7月中，被选中的变量仅有风速和850hPa地势高度——这表明这些变量在一定程度上也可解释降水过程;
4. 表格中被选中的格点基本围绕{4, 4}；因此在选择变量时，不仅要考虑其和观测降水的相关性还需考虑时间尺度上的相关性。

Table 2. Final sets of potential predictors for each calendar month.

Month	Potential variables used in the model with grid locations
January	Surface precipitation rate {(3,3),(4,4)} 1000 hPa specific humidity {(3,3),(3,4),(4,4)} 850 hPa meridional wind {(2,6),(3,5),(3,6)} 850 hPa relative humidity {(1,2)} 2 m specific humidity {(3,3),(3,4)}
February	Surface precipitation rate {(3,4),(4,4),(4,5)}
March	Surface precipitation rate {(3,3),(3,4),(3,5),(4,3),(4,4),(4,5),(4,6)}
April	850 hPa relative humidity {(4,3),(4,4)} Surface precipitation rate {(4,3)}
May	Surface precipitation rate {(4,4),(5,5)} 850 hPa geopotential height {(4,3)}
June	Surface precipitation rate {(3,2),(3,3),(4,2),(4,3),(4,4),(4,5)} Mean sea level pressure {(4,3),(5,3)} 850 hPa zonal wind {(2,4)} Surface pressure{(4,3),(5,3),(5,4)}
July	850 hPa zonal wind {(1,3),(1,4)} 850 hPa geopotential height {(4,3),(4,4),(4,5)}
August	Surface precipitation rate {(4,3),(5,4),(5,5)}
September	Surface precipitation rate {(2,1),(2,2),(3,2),(3,3),(3,5),(4,2),(4,3),(4,4),(4,5)} 850 hPa relative humidity {(3,3)} 700 hPa relative humidity {(3,4)}
October	Surface precipitation rate {(3,2),(4,2),(4,3),(4,4)} 850 hPa relative humidity {(4,3)} 700 hPa geopotential height {(1,1)}
November	850 hPa relative humidity {(3,2),(3,3)} Surface precipitation rate {(4,3),(4,5)}
December	Surface precipitation rate {(2,1),(3,2),(4,3),(4,4),(5,5)} 850 hPa relative humidity {(3,2)}

hPa, atmospheric pressure in hectopascal; the locations are given within brackets (see Figure 1).

Results

1. 该降尺度模型具有捕捉月降水特征和强度的能力。
2. 在降水较小时被高估，在降水高值区域则又被低估。

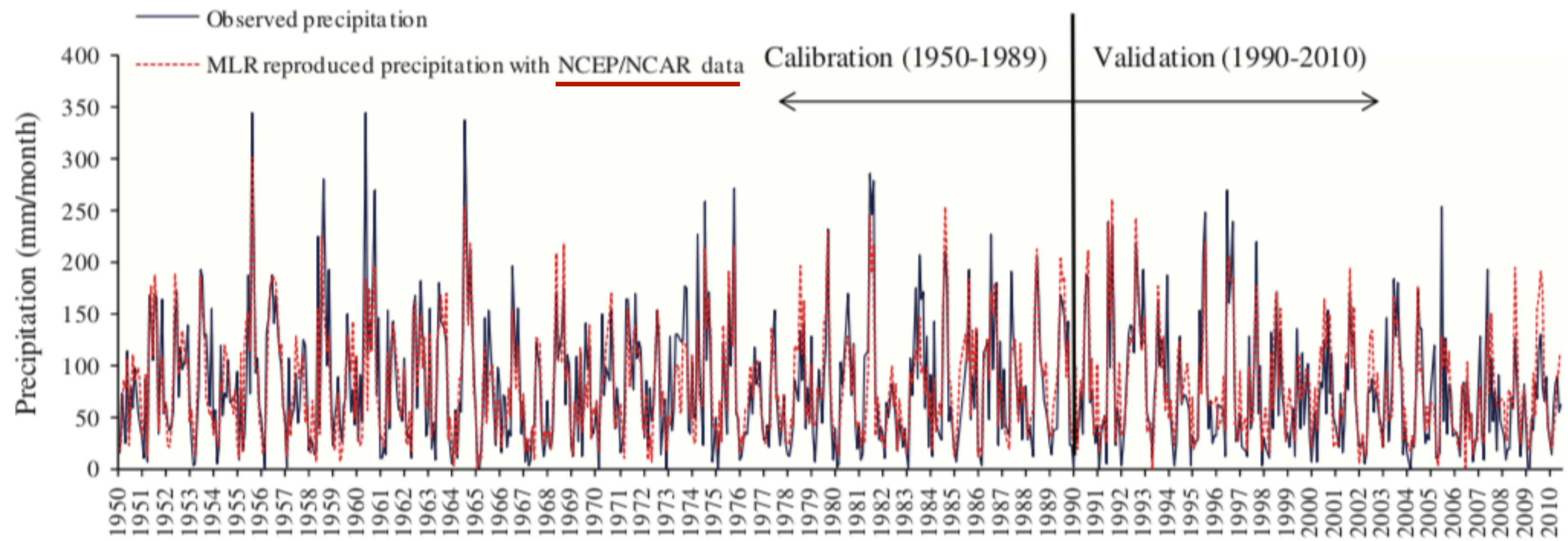


Figure 2. Observed and Model$_{(NCEP/NCAR)}$ reproduced monthly precipitation (1950 to 2010).

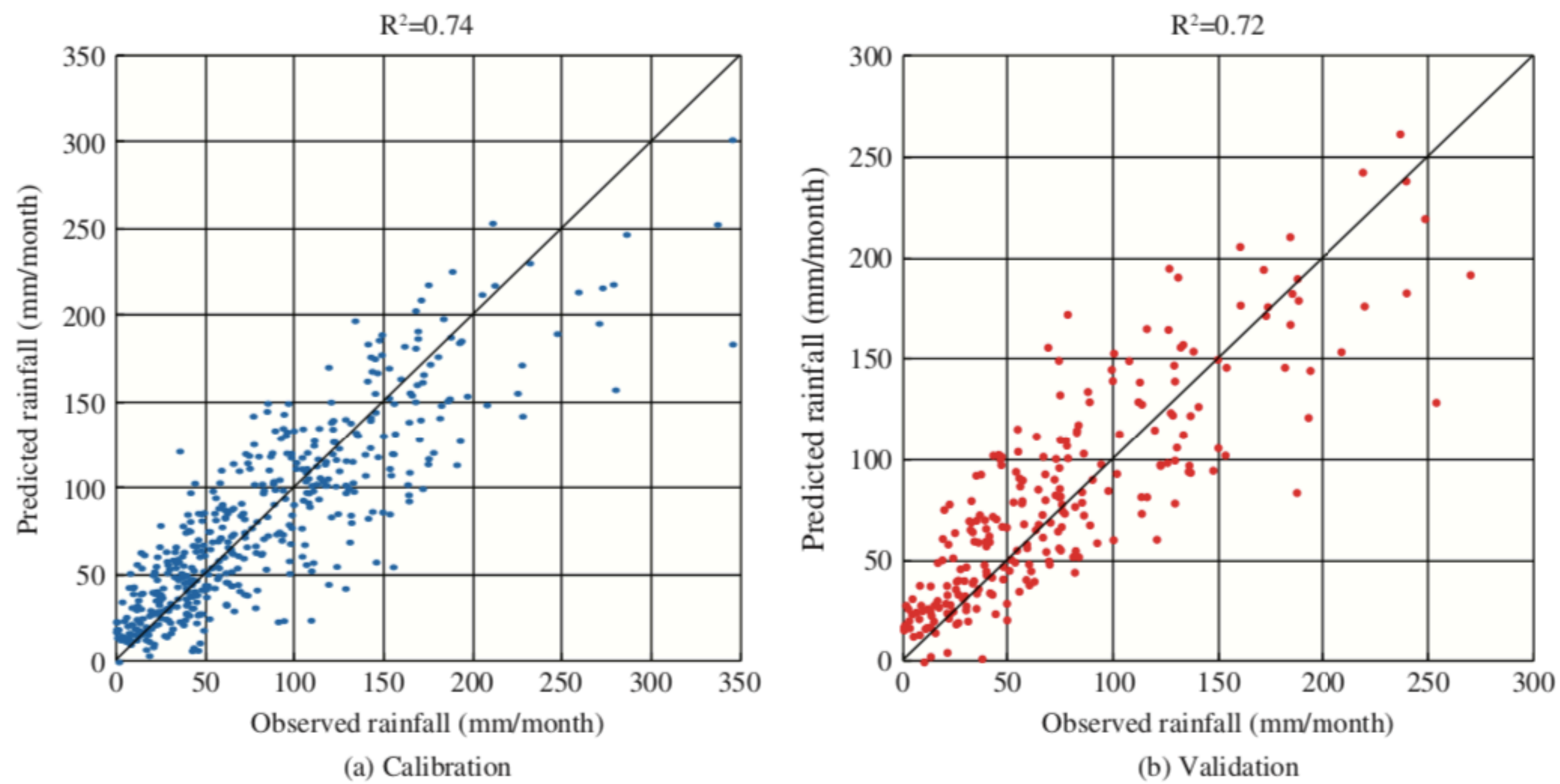
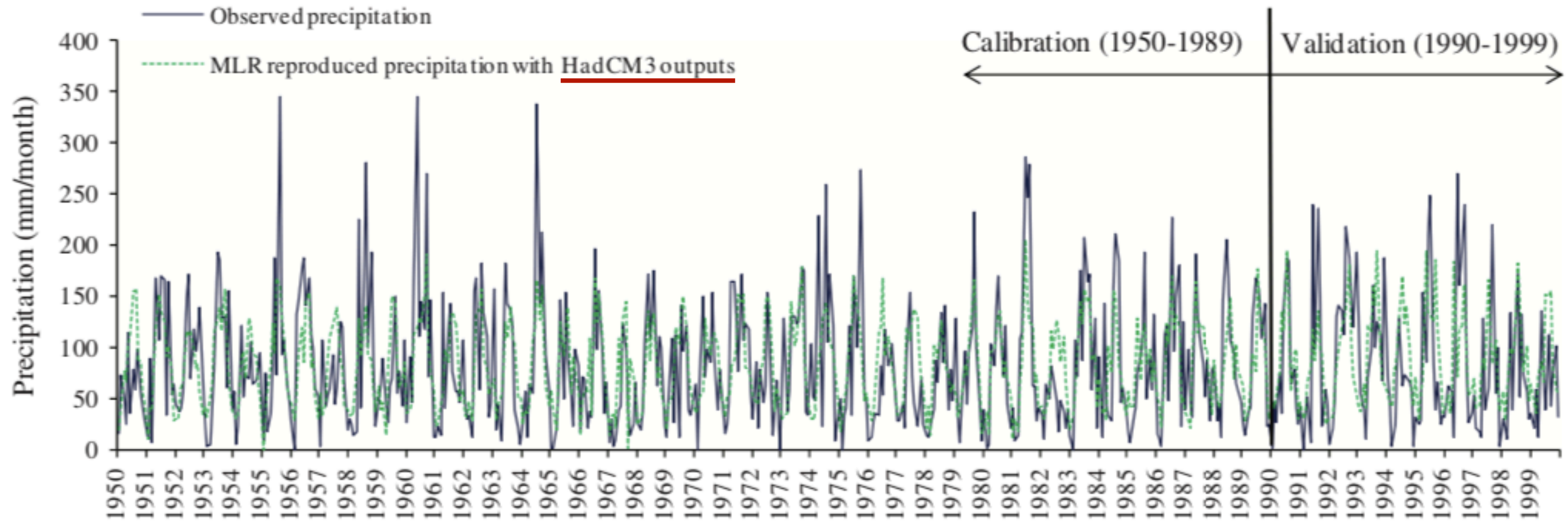
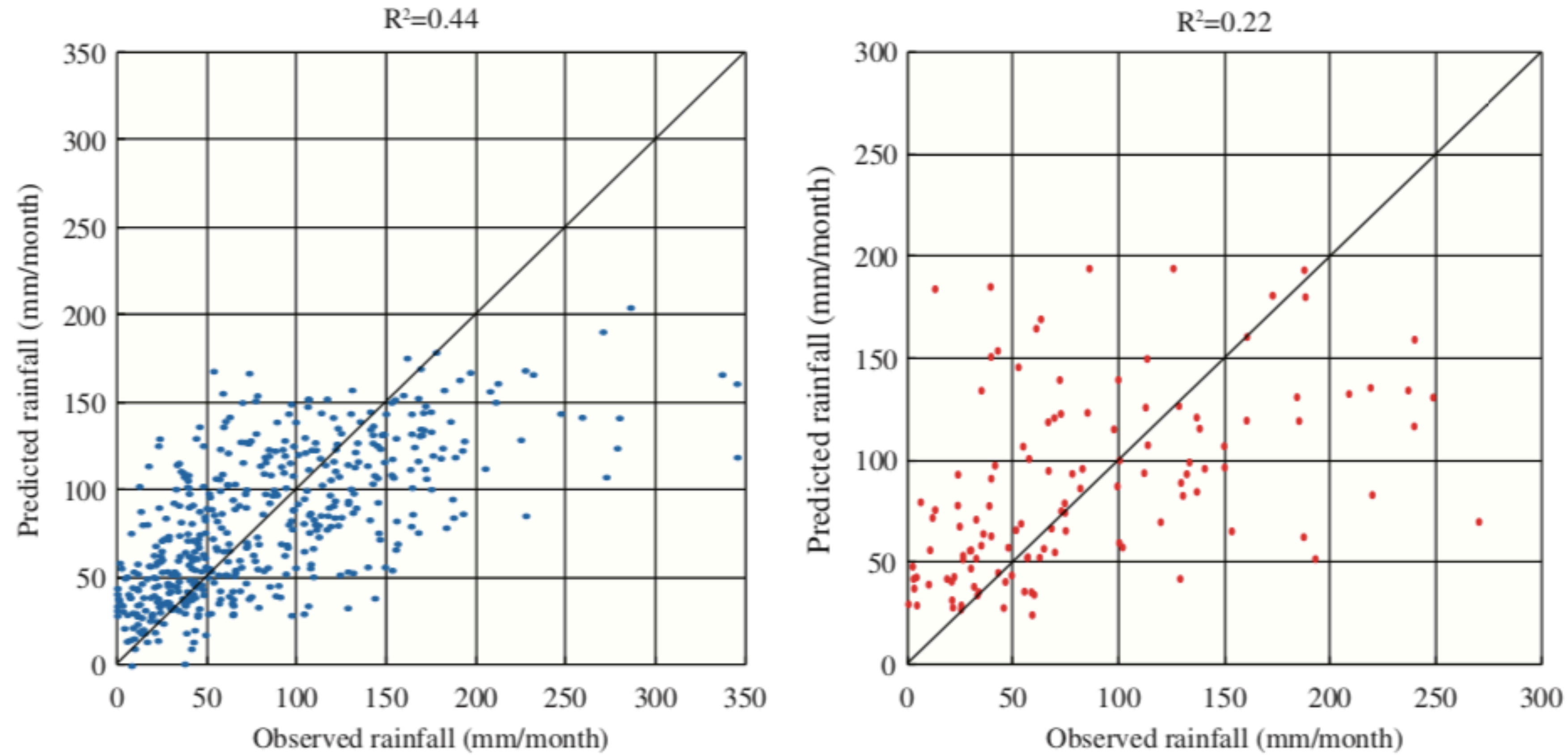


Figure 3. Scatter plots of observed and Model$_{(NCEP/NCAR)}$ reproduced monthly precipitation for calibration (1950–1989) and validation

Results

1. 该降尺度模型并未较好的重现降水的高值部分；
2. 并且，该模型对观测数据的再现不如使用NCEP/NCAR数据作为输出的模型好；
3. 然而，该模型还是可以大致捕捉了观测数据的降水特征；





(a) Calibration (b) Validation

1. 训练集和验证集中，均表现为在降水较小时被高估，在降水高值区域则又被低估；
2. 这是由于降水观测数据的方差要比GCM或再分析资料的方差大得多，因此在降尺度过程中，模型只能观测数据方差的部分，而无法表达高值和低值。

Results

1. 两个模型在训练集和验证集均对观测的平均值捕捉的很好；
2. 然而两个模型均无法正确捕捉到观测数据的标准差和方差；
3. 相较而言，使用NCEP/NCAR数据作为输出的降尺度模型表现更好。

Table 3. Performances of downscaling models in calibration and validation.

Statistic	Calibration (1950–1989)			Validation (1990–2010)/*(1990–1999)*[a]			
	Observations	$\text{Model}_{(\text{NCEP/NCAR})}$	$\text{Model}_{(\text{HadCM3})}$	Observations		$\text{Model}_{(\text{NCEP/NCAR})}$	$\text{Model}_{(\text{HadCM3})}$
				1990–2010	1990–1999		
Avg	81.8	82.0	81.7	73.3	***81.8***	81.0	***87.6***
Std	61.7	53.2	41.1	56.9	***64.3***	51.9	***44.5***
C_v	0.75	0.65	0.50	0.78	***0.79***	0.64	***0.51***
NSE		0.74	0.44			0.70	***0.17***
SANS		0.66	0.26			0.61	***−0.20***
R^2		0.74	0.44			0.72	***0.22***

Avg, average of monthly precipitation in mm; C_v, coefficient of variation; NSE, Nash–Sutcliffe efficiency; R^2, coefficient of determination; Std, standard deviation of monthly precipitation in mm; SANS, Seasonally Adjusted Nash–Sutcliffe efficiency. [a]Bold italicized values in the table refer to period 1990–1999.

Table 4. Seasonal performances of downscaling models.

Model	Statistic	Calibration (1950–1989)				Validation (1990–2010)/*(1990–1999)*[a]			
		Season				Season			
		Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring
Observed	Avg	40.7	73.7	125.1	87.7	42.9/***(44.3)***	54.1/***(57.0)***	119.4/***(136.1)***	78.3/***(89.8)***
$\text{Model}_{(\text{NCEP/NCAR})}$	Avg	40.7	73.7	125.1	87.7	49.2	57.8	132.5	85.1
$\text{Model}_{(\text{HadCM3})}$	Avg	40.3	73.8	125.1	87.8	***(44.9)***	***(78.8)***	***(128.3)***	***(98.5)***
Observed	Std	33.7	58.8	64.5	53.5	41.0/***(46.8)***	43.1/***(46.5)***	61.2/***(66.3)***	48.4/***(55.1)***
$\text{Model}_{(\text{NCEP/NCAR})}$	Std	26.0	46.6	54.1	43.9	29.8	33.1	54.1	41.7
$\text{Model}_{(\text{HadCM3})}$	Std	15.6	34.4	26.7	30.5	***(12.7)***	***(39.0)***	***(30.0)***	***(42.0)***
Observed	C_v	0.83	0.80	0.52	0.61	0.96/***(1.06)***	0.80/***(0.82)***	0.51/***(0.49)***	0.62/***(0.61)***
$\text{Model}_{(\text{NCEP/NCAR})}$	C_v	0.64	0.63	0.43	0.50	0.61	0.57	0.41	0.49
$\text{Model}_{(\text{HadCM3})}$	C_v	0.39	0.47	0.21	0.35	***(0.28)***	***(0.49)***	***(0.23)***	***(0.43)***
$\text{Model}_{(\text{NCEP/NCAR})}$	NSE	0.60	0.63	0.70	0.67	0.42	0.75	0.58	0.64
$\text{Model}_{(\text{HadCM3})}$	NSE	0.16	0.34	0.17	0.33	***(0.12)***	***(−0.58)***	***(−0.20)***	***(−0.15)***
$\text{Model}_{(\text{NCEP/NCAR})}$	R^2	0.60	0.63	0.70	0.67	0.45	0.71	0.63	0.65
$\text{Model}_{(\text{HadCM3})}$	R^2	0.16	0.34	0.17	0.33	***(0.13)***	***(0.04)***	***(0.00)***	***(0.09)***

Avg, average of monthly precipitation in mm; C_v, coefficient of variation; NSE, Nash–Sutcliffe efficiency; R^2, coefficient of determination; Std, standard deviation of monthly precipitation in mm. [a]Bold italicized values in brackets in the table refer to period 1990–1999.

Results

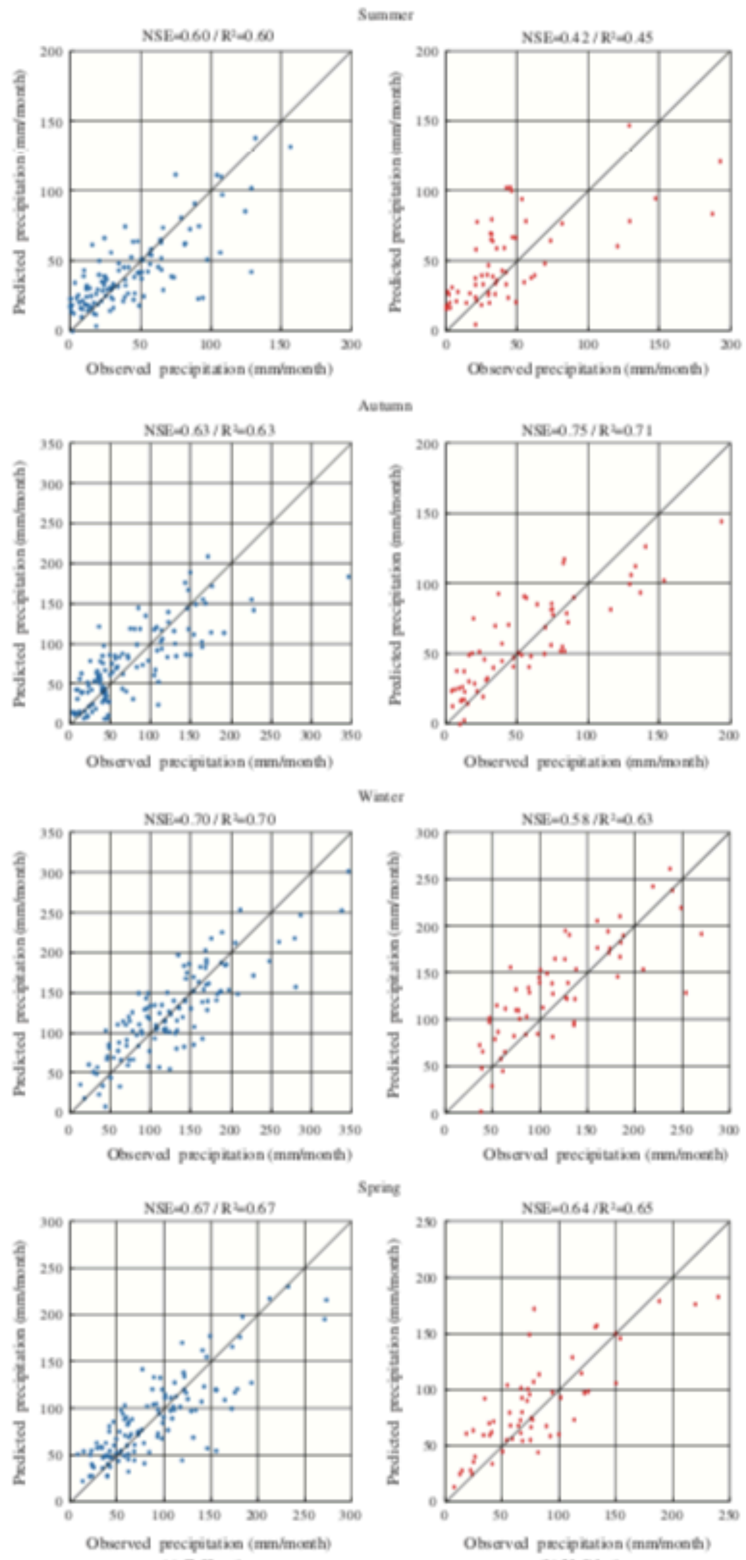


Figure 6. Seasonal scatter plots of observed and Model$_{(NCEP/NCAR)}$ reproduced monthly precipitation for calibration (1950–1989) and validation (1990–2010).

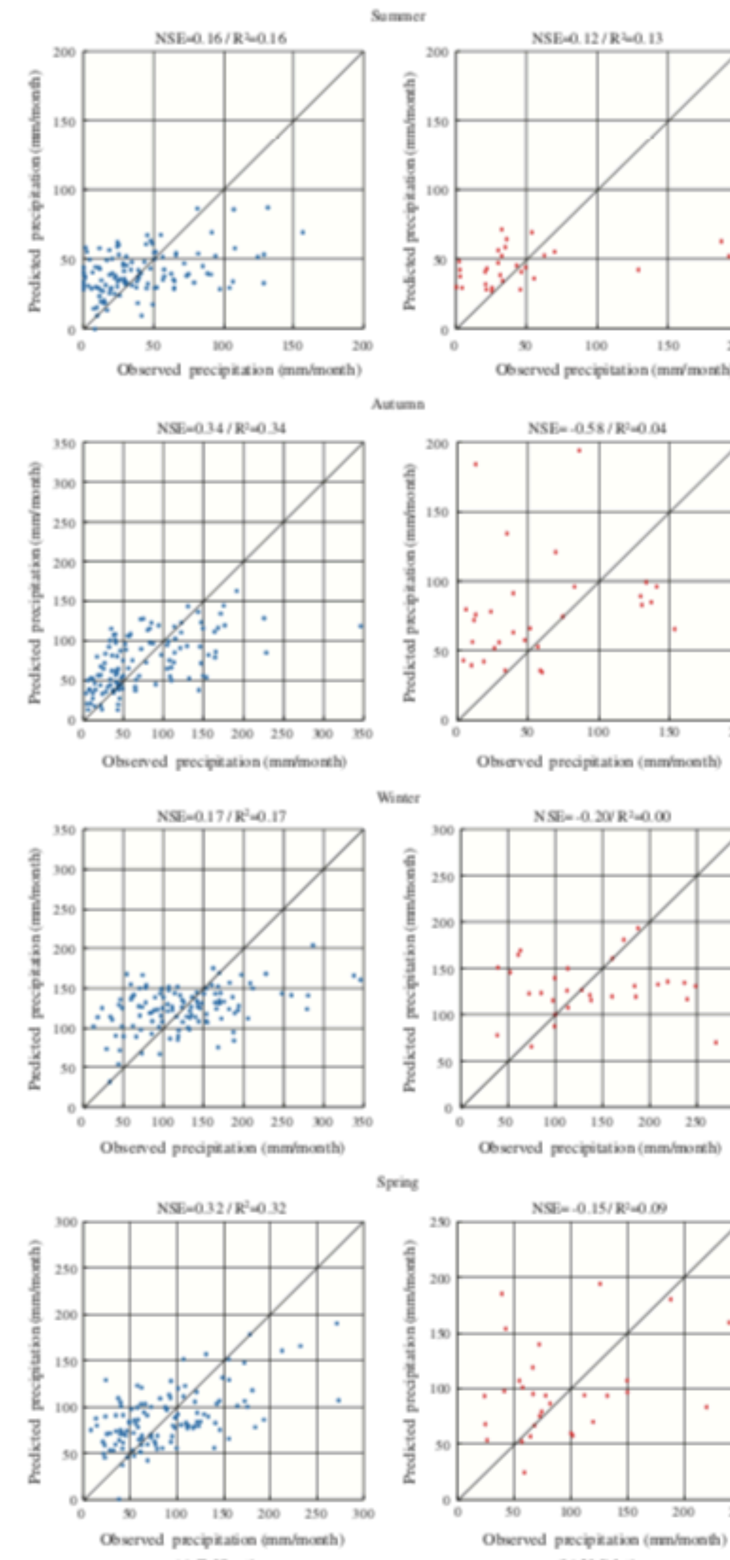


Figure 7. Seasonal scatter plots of observed and Model$_{(HadCM3)}$ reproduced monthly precipitation for calibration (1950–1989) and validation (1990–1999).

Results

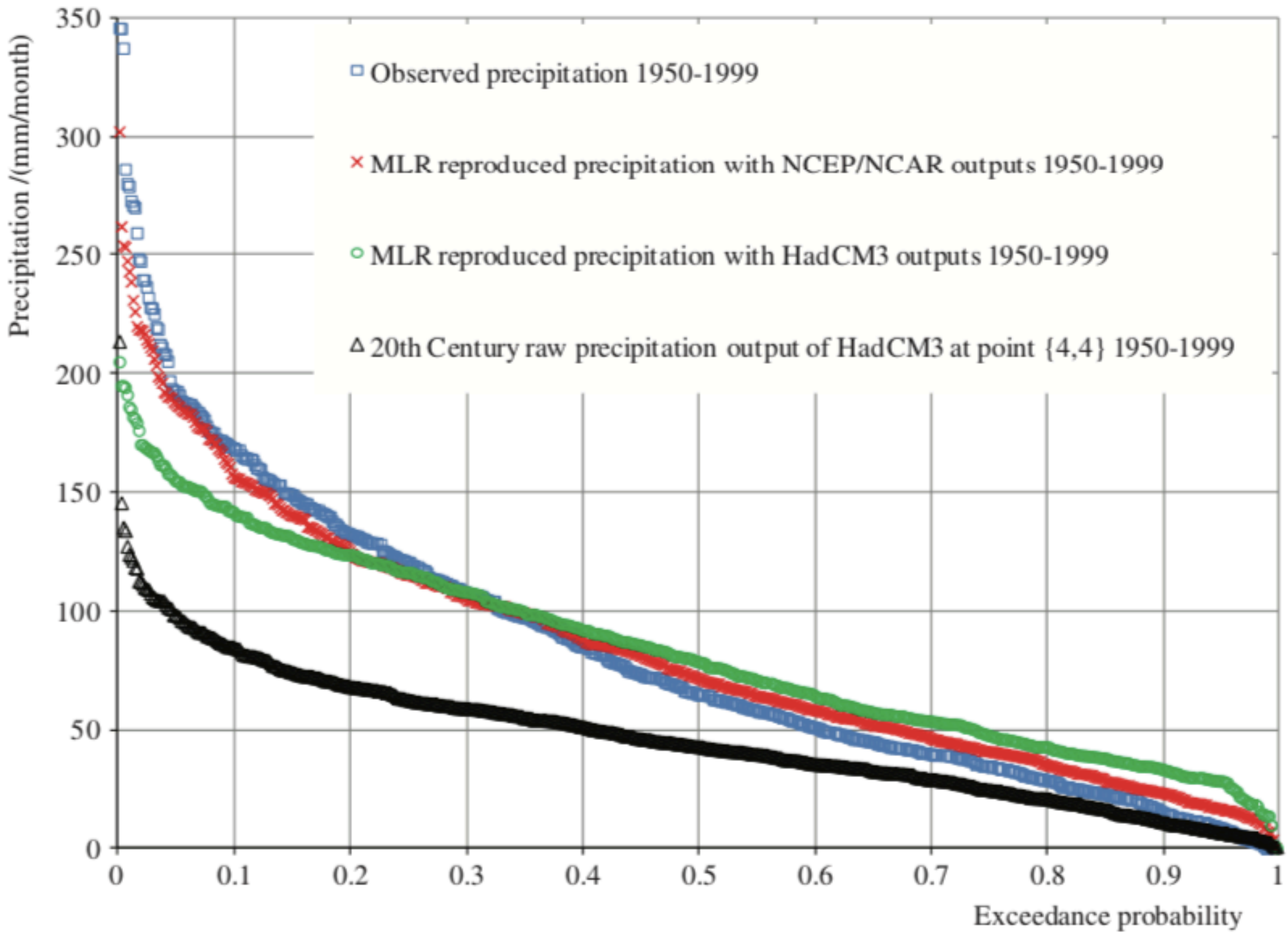


Figure 8. Precipitation probability exceedance curves (1950–1999).

Conclusions

1. 对于全年的降水，降水速率被认为是最可用于解释观测降水数据的变量（除去7月），湿度、地势高度、平均海平面高度地表压力、和风速都在整个时间段上和观测降水变量有较高的相关性；
2. 使用NCEP/NCAR作为输出的降尺度模型在训练集和验证集上均表现良好，而使用HadCM3的模型表现较差；
3. HadCM3输出和观测数据相差较大(There was a quality mismatch between the NCEP/NCAR reanalysis and HadCM3 outputs, over the period 1950–1999)。

谢谢