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## Supplement of

## Customized deep learning for precipitation bias correction and downscaling

Fang Wang et al.

Correspondence to: Di Tian (tiandi@auburn.edu)

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## **Supplemental Tables**

Table S1. Probability for each precipitation bin during training and testing periods and their difference.

Precipitation Bin (mm/h)	Train (%)	Test (%)	Test-Train (%)
0-0.5	95.637	94.377	-1.261
0.5-1.0	1.156	1.573	0.417
1.0-1.5	0.671	0.921	0.250
1.5-2.0	0.455	0.613	0.158
2.0-2.5	0.333	0.443	0.109
2.5-3.0	0.257	0.333	0.077
3.0-3.5	0.206	0.261	0.055
3.5-4.0	0.169	0.211	0.042
4.0-4.5	0.140	0.172	0.032
4.5-5.0	0.118	0.146	0.028
5.0-5.5	0.100	0.118	0.018
5.5-6.0	0.086	0.099	0.013
6.0-6.5	0.074	0.084	0.010
6.5-7.0	0.064	0.071	0.007
7.0-7.5	0.056	0.063	0.007
7.5-8.0	0.049	0.052	0.004
8.0-8.5	0.043	0.045	0.002
8.5-9.0	0.038	0.040	0.002
9.0-9.5	0.033	0.035	0.002
9.5-10	0.029	0.031	0.002
>10	0.287	0.313	0.027
sum	100.0	100.0	0.0

Table S2. Overall assessment for hourly, daily total, and monthly mean of hourly precipitation by running each scenario 4 times to consider stochastic nature of deep learning. The values outside and inside parenthesis are mean and standard deviation of the 4 runs, respectively. Significance evaluation is based on p-value 0.05 (i.e., mean ±2\* standard deviation confident intervals)

Temporal scales   Scenarios   KGE   r   β   γ   RMSE (mm) (mm) (mm) (mm) (mm) (mm) (mm) (mm								
Scenario1	Temporal scales	Scenarios*	KGE	r	ß	γ		
Northern Precipitation   Scenario   Co.0036   Co.0059   Co.0061   Co.016   Co.0038   Co.0012   Co.0013   Co.0013   Co.0070   Co.0086   Co.0128   Co.009   Co.0011   Co.0013   Co.0070   Co.0086   Co.0128   Co.009   Co.0011   Co.0013   Co.0070   Co.0086   Co.00128   Co.009   Co.0011   Co.0013   Co.0013   Co.0013   Co.0013   Co.0013   Co.0014   Co.0012   Co.0015   Co.0013   Co.0013   Co.0014   Co.0012   Co.0015   Co.0013   Co.0014   Co.0012   Co.0015   Co.0013   Co.0014   C	portar sources	_ 30111100						
Non-third Precipitation   Scenario2   O.217   O.295   O.960   O.660   O.125   O.259		Scenario1						
Hourly precipitation   Scenario2   (0.0013)   (0.0070)   (0.0086)   (0.0128)   (0.009)   (0.0011)   (0.0013)   (0.0030)   (0.0055)   (0.0074)   (0.0132)   (0.010)   (0.0013)   (0.0014)   (0.0014)   (0.0015)   (0.0026)   (0.0029)   (0.0102)   (0.0055)   (0.0036)   (0.0014)   (0.0015)   (0.0028)   (0.0042)   (0.0099)   (0.0034)   (0.0014)   (0.0015)   (0.0028)   (0.0042)   (0.0099)   (0.0034)   (0.0014)			` /	` /	,			
Hourly precipitation   Scenario3   0.003   0.0070   0.0088   0.0128   0.0099   0.0011)		Scenario2						
Hourly precipitation   Scenario4   0.0030   0.0055   0.0074   0.0132   0.0101   0.00131			,	` ′	,	,	` ,	` '
Hourly precipitation   Scenario4   0.048   0.0248   0.328   0.878   0.686   1.21   0.241   0.0036)   0.00036   0.0029   0.0102   0.0005   0.00036   0.0036   0.0028   0.00029   0.0102   0.0005   0.00036   0.0028   0.00042   0.0009   0.00034   0.0042   0.0009   0.00034   0.0042   0.0009   0.00034   0.0042   0.0009   0.00034   0.0042   0.0009   0.00034   0.0004		Scenario3						
Daily precipitation   Scenario4   0.248   0.328   0.378   0.086   1.21   0.245   0.0006   0.0006   0.0006   0.0006   0.0006   0.0006   0.0006   0.0006   0.0006   0.0006   0.0006   0.0007   0.0008   0			` /	,	, ,		` /	, ,
No.		Scenario4						
Scenario			(0.0017)	, ,	, ,	, ,	, ,	(0.0036)
No.		Scenario5						
No.			` /	` ,	` ,	,	` /	` '
QDM_BI   0.248   0.332   1.02   1.35   1.36   0.256		Scenario6						
Scenario1			` /		. ,	,		,
Nonthly mean of hourly precipitation   Scenario2   (0.0126)   (0.0049)   (0.0049)   (0.0062)   (0.023)   (0.03)   (0.009)   (0.0099)   (0.0045)   (0.0087)   (0.0035)   (0.06)   (0.020)   (0.0046)   (0.0046)   (0.0048)   (0.0075)   (0.0079)   (0.07)   (0.0114)   (0.0043)   (0.0075)   (0.0079)   (0.07)   (0.0114)   (0.0043)   (0.0075)   (0.0079)   (0.077)   (0.0144)   (0.011)   (0.0043)   (0.030)   (0.013)   (0.044)   (0.0444		QDM_BI						
Scenario2   0.642   0.683   0.960   0.840   8.80   3.44		Scanario 1						
Daily precipitation   Scenario2   (0.0034)   (0.0045)   (0.0087)   (0.0035)   (0.06)   (0.020)		Sechanor						. ,
Daily precipitation		Scenario?						
Daily precipitation   Scenario3   (0.0046)   (0.0048)   (0.0075)   (0.0079)   (0.07)   (0.014)	Deile	Scenario2	, ,	(0.0045)	(0.0087)	(0.0035)	. ,	. ,
Daily precipitation   Scenario4   0.609   0.637   0.878   0.930   9.42   3.57		Scenario3	0.629	0.680	1.01	0.814	8.87	3.52
Descriptation   Scenario4   (0.011)   (0.0043)   (0.030)   (0.013)   (0.044)   (0.044)   (0.044)   (0.044)   (0.044)   (0.0043)   (0.030)   (0.013)   (0.044)   (0.044)   (0.044)   (0.044)   (0.044)   (0.044)   (0.044)   (0.044)   (0.044)   (0.044)   (0.044)   (0.044)   (0.042)   (0.0073)   (0.0075)   (0.10)   (0.055)   (0.0076)   (0.0076)   (0.0072)   (0.016)   (0.10)   (0.080)   (0.0072)   (0.016)   (0.10)   (0.080)   (0.0072)   (0.016)   (0.0072)   (0.016)   (0.0072)   (0.0002)   (0.0002)   (0.0003)   (0.0002)   (0.0003)   (0.0002)   (0.0003)   (0.0002)   (0.0002)   (0.0002)   (0.0002)   (0.0003)   (0.0002)   (0.0002)   (0.0003)   (0.0002)   (0.0002)   (0.0001)   (0.000			,	(0.0048)	(0.0075)	(0.0079)	` /	(0.014)
Scenario5   0.689   0.703   0.986   0.912   8.77   3.34	•	Scenario4						
Scenario5	precipitation		(0.011)	(0.0043)	(0.030)	(0.013)	(0.04)	(0.044)
Scenario6   0.666   0.698   0.965   0.876   8.70   3.32     QDM_BI   0.644   0.689   1.02   1.17   10.50   3.42     Scenario1   -0.0076   0.559   0.282   1.55   0.164   0.134     Scenario2   0.768   0.779   0.961   0.946   0.072   0.051     Monthly mean of hourly precipitation   Scenario5   0.675   0.700   0.878   0.986   0.085   0.060     Scenario5   0.776   0.778   0.987   0.980   0.074   0.052     Scenario6   0.765   0.779   0.964   0.966   0.074   0.052     Scenario6   0.019   0.0090   0.0072   0.016   0.0016   0.0011		Scenario5						
Nonthly mean of hourly precipitation   Scenario6   (0.013)   (0.0045)   (0.072)   (0.016)   (0.10)   (0.080)   (0.072)   (0.016)   (0.10)   (0.080)   (0.0045)   (0.016)   (0.016)   (0.011)   (0.00			` ,	` ,	(0.028)	,	` '	` /
QDM BI   0.644   0.689   1.02   1.17   10.50   3.42		Scenario6	0.666	0.698	0.965	0.876	8.70	3.32
Scenario1			(0.013)	(0.0045)	(0.072)	(0.016)	` /	(0.080)
$ \begin{array}{c} Scenario1 \\ Scenario2 \\ \hline \\ Scenario2 \\ \hline \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ $		QDM_BI	0.644	0.689	1.02	1.17	10.50	3.42
	hourly	Scenario1	-0.0076	0.559	0.282	1.55	0.164	0.134
Monthly mean of hourly precipitation   Scenario2   (0.0071)   (0.0087)   (0.0088)   (0.013)   (0.0016)   (0.0011)   (0.0011)   (0.0087)   (0.0088)   (0.013)   (0.0016)   (0.0011)   (0.0016)   (0.0051)   (0.0072)   (0.0076)   (0.017)   (0.0010)   (0.0006)   (0.0072)   (0.0076)   (0.017)   (0.0010)   (0.0006)   (0.0074)   (0.0072)   (0.0088)   (0.017)   (0.0018)   (0.0009)   (0.0018)   (0.0009)   (0.0018			(0.0191)	,	(0.0062)	,	` ,	
		Scenario2	0.768	0.779	0.961	0.946	0.072	0.051
Monthly mean of hourly precipitation         Scenario3         (0.0090)         (0.0072)         (0.0076)         (0.017)         (0.0010)         (0.0006)           Nourly precipitation         Scenario4         0.675         0.700         0.878         0.986         0.085         0.060           Nourly precipitation         0.017         (0.0092)         (0.029)         (0.012)         (0.0018)         (0.0009)           Nourly precipitation         0.776         0.778         0.987         0.980         0.074         0.052           Nourly precipitation         0.765         0.779         0.964         0.966         0.074         0.052           Nourly precipitation         0.019         0.0090         0.0722         0.016         0.0016         0.0011			(0.0071)	(0.0087)	(0.0088)	(0.013)	(0.0016)	(0.0011)
Monthly mean of hourly precipitation   Scenario4   0.675   0.700   0.878   0.986   0.085   0.060   0.017   (0.0008)		Scenario3	0.772	0.785	1.01	0.927	0.072	0.051
precipitation   Scenario4   (0.017)   (0.0092)   (0.029)   (0.012)   (0.0018)   (0.0009)   (0.012)   (0.0018)   (0.0009)   (0.012)   (0.0018)   (0.0009)   (0.012)   (0.012)   (0.0018)   (			(0.0090)	(0.0072)	(0.0076)	(0.017)	(0.0010)	(0.0006)
Scenario 6 (0.017) (0.0092) (0.029) (0.012) (0.0018) (0.0009)  Scenario 5 (0.0033) (0.0027) (0.028) (0.015) (0.0002) (0.0003)  Scenario 6 (0.019) (0.0090) (0.072) (0.016) (0.0016) (0.0011)		Scenario4	0.675	0.700	0.878	0.986	0.085	0.060
Scenario5 (0.0033) (0.0027) (0.028) (0.015) (0.0002) (0.0003)  Scenario6 (0.019) (0.0090) (0.072) (0.016) (0.0016) (0.0011)			(0.017)	(0.0092)	(0.029)	(0.012)	(0.0018)	(0.0009)
Scenario6 (0.0033) (0.0027) (0.028) (0.013) (0.0002) (0.0003) (0.0003) (0.0027) (0.028) (0.013) (0.0002) (0.0003) (0.000		Scenario5	0.776	0.778	0.987	0.980	0.074	0.052
Scenario6 (0.019) (0.0090) (0.072) (0.016) (0.0016) (0.0011)			(0.0033)	(0.0027)	(0.028)	(0.015)	(0.0002)	(0.0003)
(0.019) $(0.0090)$ $(0.072)$ $(0.016)$ $(0.0016)$ $(0.0011)$		Scenario6	0.765	0.779	0.964	0.966	0.074	0.052
QDM BI 0.717 0.777 1.02 1.17 0.0850 0.0553			(0.019)	(0.0090)	(0.072)	(0.016)	(0.0016)	(0.0011)
		QDM BI	0.717	0.777	1.02	1.17	0.0850	0.0553

<sup>\*</sup>Scenarios have different settings: Scenario1 is with a regular MAE loss function and coarse precipitation as a predictor; Scenario2 is with a weighted MAE loss and coarse precipitation as a predictor; Scenario3 is the same as Scenario2 except with a classification as an auxiliary task; Scenario4 is with a weighted loss function and covariates as predictors; Scenario5 is the same as Scenario4 except also including coarse precipitation as predictors; Scenario 6 is the same as Scenario5 but including a classification as an auxiliary task.

Table S3. Performance of extreme indices including hourly P at 99% percentile and annual maximum wet spell in hours by running each scenario 4 times to consider stochastic nature of deep learning. The values outside and inside parenthesis are mean and standard deviation of the 4 runs, respectively.

Extreme indices	Scenarios*	KGE	r	β	γ	RMSE	MAE
004	Scenario1	-1.47	0.330	0.355	3.29	3.17	3.12
		(0.180)	(0.036)	(0.004)	(0.190)	(0.018)	(0.020)
	Scenario2	0.358	0.422	0.806	1.19	1.07	0.96
		(0.030)	(0.028)	(0.006)	(0.074)	(0.020)	(0.027)
	Scenario3	0.255	0.283	0.826	1.08	1.01	0.89
		(0.016)	(0.016)	(0.010)	(0.069)	(0.032)	(0.032)
99th percentile	Scenario4	0.202	0.240	0.765	1.02	1.25	1.15
(mm)		(0.015)	(0.022)	(0.017)	(0.070)	(0.077)	(0.082)
	Camania 5	0.265	0.293	0.837	1.11	0.969	0.85
	Scenario5	(0.008)	(0.008)	(0.026)	(0.051)	(0.104)	(0.108)
	Scenario6	0.238	0.274	0.808	1.11	0.981	0.87
		(0.009)	(0.0037)	(0.055)	(0.051)	(0.042)	(0.055)
	QDM_BI	0.158	0.244	0.900	1.36	0.793	0.655
	Scenario1	0.156	0.308	0.645	1.32	11.7	9.77
		(0.0028)	(0.0247)	(0.016)	(0.071)	(0.35)	(0.34)
Annual maximum wet spell (hours)	Scenario2	0.311	0.320	1.10	0.999	9.26	7.06
		(0.028)	(0.023)	(0.040)	(0.018)	(0.85)	(0.60)
	Scenario3	0.273	0.282	1.09	1.01	9.24	7.02
		(0.012)	(0.014)	(0.022)	(0.070)	(0.22)	(0.064)
	Scenario4	0.125	0.248	1.40	1.20	16.3	12.0
		(0.008)	(0.023)	(0.048)	(0.037)	(1.2)	(0.64)
	Scenario5	0.186	0.319	1.43	1.10	15.6	11.9
		(0.013)	(0.017)	(0.010)	(0.010)	(0.24)	(0.22)
	Scenario6	0.151	0.288	1.43	1.16	16.0	11.9
		(0.0049)	(0.018)	(0.032)	(0.020)	(1.13)	(0.70)
	QDM_BI	-0.209	0.173	1.88	1.09	26.6	22.2

<sup>\*</sup>Scenarios have different settings: Scenario1 is with a regular MAE loss function and coarse precipitation as a predictor; Scenario2 is with a weighted MAE loss and coarse precipitation as a predictor; Scenario3 is the same as Scenario2 except with a classification as an auxiliary task; Scenario4 is with a weighted loss function and covariates as predictors; Scenario5 is the same as Scenario4 except also including coarse precipitation as predictors; Scenario 6 is the same as Scenario5 but including a classification as an auxiliary task.

## **Supplemental Figures**

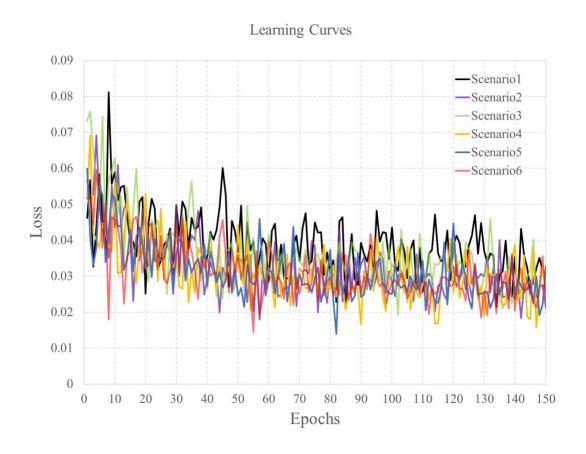


Figure S1. Learning curves for the 6 scenarios