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# Customized deep learning for precipitation bias correction and downscaling

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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) | MAE (mm) |
|---|---|---|---|---|---|---|---|
| Hourly precipitation | Scenario1 | -0.0547 (0.0036) | 0.275 (0.0059) | 0.281 (0.0061) | 1.26 (0.016) | 1.20 (0.0038) | 0.188 (0.0012) |
| | Scenario2 | 0.217 (0.0013) | 0.295 (0.0070) | 0.960 (0.0086) | 0.660 (0.0128) | 1.25 (0.009) | 0.259 (0.0011) |
| | Scenario3 | 0.205 (0.0030) | 0.285 (0.0055) | 1.01 (0.0074) | 0.652 (0.0132) | 1.27 (0.010) | 0.268 (0.0013) |
| | Scenario4 | 0.248 (0.0017) | 0.328 (0.0026) | 0.878 (0.029) | 0.686 (0.0102) | 1.21 (0.005) | 0.241 (0.0036) |
| | Scenario5 | 0.282 (0.0016) | 0.357 (0.0015) | 0.986 (0.028) | 0.681 (0.0042) | 1.22 (0.009) | 0.245 (0.0034) |
| | Scenario6 | 0.264 (0.0036) | 0.355 (0.0021) | 0.965 (0.072) | 0.654 (0.0142) | 1.20 (0.013) | 0.243 (0.0081) |
| | QDM_BI | 0.248 | 0.332 | 1.02 | 1.35 | 1.36 | 0.256 |
| Daily precipitation | Scenario1 | 0.0791 (0.0126) | 0.617 (0.0049) | 0.281 (0.0062) | 1.43 (0.023) | 10.2 (0.03) | 3.56 (0.009) |
| | Scenario2 | 0.642 (0.0034) | 0.683 (0.0045) | 0.960 (0.0087) | 0.840 (0.0035) | 8.80 (0.06) | 3.44 (0.020) |
| | Scenario3 | 0.629 (0.0046) | 0.680 (0.0048) | 1.01 (0.0075) | 0.814 (0.0079) | 8.87 (0.07) | 3.52 (0.014) |
| | Scenario4 | 0.609 (0.011) | 0.637 (0.0043) | 0.878 (0.030) | 0.930 (0.013) | 9.42 (0.04) | 3.57 (0.044) |
| | Scenario5 | 0.689 (0.0020) | 0.703 (0.0018) | 0.986 (0.028) | 0.912 (0.0075) | 8.77 (0.10) | 3.34 (0.055) |
| | Scenario6 | 0.666 (0.013) | 0.698 (0.0045) | 0.965 (0.072) | 0.876 (0.016) | 8.70 (0.10) | 3.32 (0.080) |
| | QDM_BI | 0.644 | 0.689 | 1.02 | 1.17 | 10.50 | 3.42 |
| Monthly mean of hourly precipitation | Scenario1 | -0.0076 (0.0191) | 0.559 (0.0081) | 0.282 (0.0062) | 1.55 (0.025) | 0.164 (0.0011) | 0.134 (0.0011) |
| | Scenario2 | 0.768 (0.0071) | 0.779 (0.0087) | 0.961 (0.0088) | 0.946 (0.013) | 0.072 (0.0016) | 0.051 (0.0011) |
| | Scenario3 | 0.772 (0.0090) | 0.785 (0.0072) | 1.01 (0.0076) | 0.927 (0.017) | 0.072 (0.0010) | 0.051 (0.0006) |
| | Scenario4 | 0.675 (0.017) | 0.700 (0.0092) | 0.878 (0.029) | 0.986 (0.012) | 0.085 (0.0018) | 0.060 (0.0009) |
| | Scenario5 | 0.776 (0.0033) | 0.778 (0.0027) | 0.987 (0.028) | 0.980 (0.015) | 0.074 (0.0002) | 0.052 (0.0003) |
| | Scenario6 | 0.765 (0.019) | 0.779 (0.0090) | 0.964 (0.072) | 0.966 (0.016) | 0.074 (0.0016) | 0.052 (0.0011) |
| | QDM_BI | 0.717 | 0.777 | 1.02 | 1.17 | 0.0850 | 0.0553 |

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

*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**

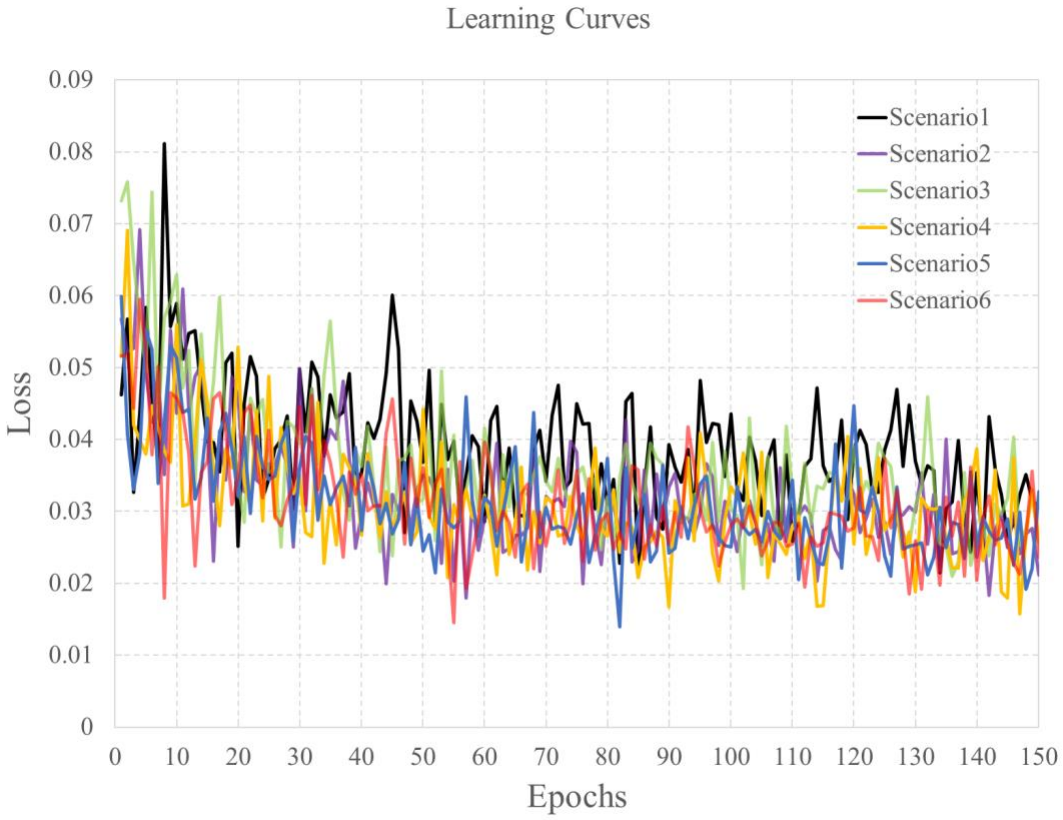


Figure S1. Learning curves for the 6 scenarios