***PAPER 1: HYBRID MLP***

***# Traditional*1.** MLP  
**2.** RNN   
**3.** LSTM   
  
***# Evolutionary***   
**1.** GA-MLP  
**2.** DE-MLP  
  
***# Swarm***   
**1.** PSO-MLP  
**2.** WOA-MLP  
  
***# Physics (Our proposed)*1. Wind Driven Optimization (WDO) - 2013 - WDO- MLP  
2. Multi-Verse Optimizer (MVO) - 2016 - MVO- MLP  
2. Equilibrium Optimizer (EO) - 2019 - EO- MLP**

***PAPER 2: HYBRID LSTM***

***# Traditional*1.** MLP  
**2.** RNN   
**3.** LSTM   
  
***# Evolutionary*1.** GA-LSTM   
**2.** DE-LSTM  
  
***# Swarm*1.** PSO-LSTM  
**2.** WOA-LSTM (Whale)  
  
***# Physics (Our proposed)*1. Wind Driven Optimization (WDO) - 2013 - WDO-LSTM   
2. Multi-Verse Optimizer (MVO) - 2016 - MVO-LSTM  
2. Equilibrium Optimizer (EO) - 2019 - EO-LSTM**

**Paper 1: Hybrid MLP**

**Table 1: Bảng kết quả cho bộ dữ liệu daily rainfall**

* 3 model cuối là của mình đề xuất: WDO-MLP, MVO-MLP, EO-MLP

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Error | Statistics | MLP | RNN | LSTM | GA-MLP | DE-MLP | PSO-MLP | WOA-MLP | **WDO-MLP** | **MVO-MLP** | **EO-MLP** |
| EV | Min | 0.261 | 0.127 | 0.235 | **0.271** | 0.21 | 0.257 | 0.228 | 0.26 | 0.234 | 0.245 |
| Max | 0.28 | 0.259 | 0.261 | 0.280 | 0.278 | 0.28 | 0.277 | 0.279 | **0.283** | 0.281 |
| Mean | 0.274 | 0.226 | 0.246 | **0.276** | 0.251 | 0.271 | 0.257 | 0.27 | 0.264 | 0.265 |
| Std | 0.006 | 0.039 | 0.009 | **0.003** | 0.021 | 0.007 | 0.017 | 0.008 | 0.018 | 0.012 |
| Cv | 0.021 | 0.174 | 0.037 | **0.012** | 0.082 | 0.025 | 0.064 | 0.029 | 0.066 | 0.047 |
| RMSE | Min | 12.667 | 12.828 | 12.818 | 12.624 | 12.648 | 12.663 | 12.673 | 12.647 | **12.622** | 12.637 |
| Max | 12.802 | 13.994 | 13.081 | **12.736** | 13.547 | 12.856 | 13.089 | 12.945 | 13.06 | 12.954 |
| Mean | 12.709 | 13.138 | 12.959 | **12.688** | 12.968 | 12.729 | 12.856 | 12.776 | 12.79 | 12.781 |
| Std | **0.04** | 0.345 | 0.09 | 0.032 | 0.27 | 0.058 | 0.15 | 0.103 | 0.155 | 0.108 |
| Cv | **0.003** | 0.026 | 0.007 | 0.003 | 0.021 | 0.005 | 0.012 | 0.008 | 0.012 | 0.008 |
| MAE | Min | 7.77 | 7.944 | 8.008 | 7.81 | **7.173** | 7.802 | 7.815 | 7.669 | 7.8 | 7.796 |
| Max | 8.027 | 9.009 | 8.429 | 7.999 | 8.219 | 7.927 | 8.446 | 8.632 | 7.982 | **7.919** |
| Mean | 7.899 | 8.344 | 8.183 | 7.872 | **7.595** | 7.881 | 8.001 | 8.032 | 7.878 | 7.849 |
| Std | 0.084 | 0.296 | 0.131 | 0.064 | 0.421 | **0.04** | 0.18 | 0.322 | 0.056 | 0.045 |
| Cv | 0.011 | 0.035 | 0.016 | 0.008 | 0.055 | 0.005 | 0.023 | 0.04 | 0.007 | **0.006** |
| SMAPE | Min | 108.983 | 110.016 | 110.185 | 109.357 | **107.906** | 109.243 | 109.326 | 109.127 | 109.229 | 109.172 |
| Max | 110.125 | 113.247 | 111.472 | 109.891 | 143.379 | 109.861 | 111.266 | 111.743 | 110.401 | **109.637** |
| Mean | 109.656 | 111.248 | 110.776 | 109.53 | 112.595 | 109.54 | 110.038 | 110.154 | 109.548 | **109.301** |
| Std | 0.323 | 0.897 | 0.392 | 0.185 | 10.866 | 0.2 | 0.539 | 0.903 | 0.347 | **0.16** |
| Cv | 0.003 | 0.008 | 0.004 | 0.002 | 0.097 | 0.002 | 0.005 | 0.008 | 0.003 | **0.001** |

**Table 2: Bảng kết quả cho bộ dữ liệu weekly rainfall**

* 3 model cuối là của mình đề xuất: WDO-MLP, MVO-MLP, EO-MLP

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Error | Statistics | MLP | RNN | LSTM | GA-MLP | DE-MLP | PSO-MLP | WOA-MLP | **WDO-MLP** | **MVO-MLP** | **EO-MLP** |
| EV | Min | -0.069 | -0.057 | -0.103 | **0.209** | 0.1 | 0.15 | 0.158 | 0.157 | 0.188 | 0.155 |
| Max | **0.234** | 0.091 | 0.078 | 0.228 | 0.247 | 0.226 | 0.229 | 0.216 | 0.228 | 0.211 |
| Mean | 0.119 | 0.046 | 0.015 | **0.221** | 0.199 | 0.202 | 0.198 | 0.2 | 0.203 | 0.183 |
| Std | 0.113 | 0.054 | 0.06 | **0.006** | 0.042 | 0.024 | 0.024 | 0.018 | 0.013 | 0.018 |
| Cv | 0.952 | 1.164 | 4.004 | **0.026** | 0.21 | 0.119 | 0.121 | 0.089 | 0.066 | 0.097 |
| RMSE | Min | 7.632 | 8.337 | 8.523 | 7.595 | **7.221** | 7.565 | 7.668 | 7.698 | 7.569 | 7.701 |
| Max | 8.937 | 9.522 | 9.749 | **7.741** | 8.548 | 8.038 | 8.035 | 8.124 | 7.784 | 7.83 |
| Mean | 8.176 | 8.753 | 8.998 | **7.666** | 7.868 | 7.685 | 7.821 | 7.847 | 7.683 | 7.754 |
| Std | 0.481 | 0.407 | 0.41 | 0.046 | 0.459 | 0.142 | 0.118 | 0.144 | 0.066 | **0.042** |
| Cv | 0.059 | 0.046 | 0.046 | 0.006 | 0.058 | 0.019 | 0.015 | 0.018 | 0.009 | **0.005** |
| MAE | Min | 5.504 | 6.054 | 6.396 | 5.443 | **4.637** | 5.285 | 5.523 | 5.474 | 5.33 | 5.451 |
| Max | 6.416 | 7.578 | 7.793 | 5.655 | 6.73 | 5.815 | 5.945 | 6.069 | **5.583** | 5.686 |
| Mean | 5.955 | 6.706 | 6.989 | 5.532 | 5.706 | 5.488 | 5.686 | 5.754 | **5.466** | 5.554 |
| Std | 0.345 | 0.476 | 0.451 | 0.068 | 0.643 | 0.144 | 0.121 | 0.2 | 0.08 | **0.078** |
| Cv | 0.058 | 0.071 | 0.065 | **0.012** | 0.113 | 0.026 | 0.021 | 0.035 | 0.015 | 0.014 |
| SMAPE | Min | 75.417 | 78.841 | 81.258 | 75.017 | 68.672 | 73.768 | 75.65 | 74.872 | 73.638 | 74.835 |
| Max | 81.816 | 88.579 | 89.739 | 76.406 | 83.806 | 77.248 | 78.111 | 79.082 | 76.054 | 79.975 |
| Mean | 78.311 | 83.33 | 85.081 | 75.608 | 76.78 | 75.329 | 76.563 | 77.051 | 75.061 | 76.095 |
| Std | 2.074 | 2.956 | 2.709 | 0.472 | 4.619 | 0.964 | 0.793 | 1.42 | 0.71 | 1.49 |
| Cv | 0.026 | 0.035 | 0.032 | 0.006 | 0.06 | 0.013 | 0.01 | 0.018 | 0.009 | 0.02 |

**Paper 2: Hybrid LSTM**

**Table 1: Bảng kết quả cho bộ dữ liệu daily rainfall**

* 3 model cuối là của mình đề xuất: WDO-LSTM, MVO-LSTM, EO-LSTM

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Error | Statistics | MLP | RNN | LSTM | GA- LSTM | DE- LSTM | PSO- LSTM | WOA-LSTM | **WDO-LSTM** | **MVO-LSTM** | **EO-LSTM** |
| EV | Min | 0.261 | 0.127 | 0.235 | **0.272** | 0.256 | 0.249 | 0.26 | 0.218 | 0.26 | 0.211 |
| Max | **0.28** | 0.259 | 0.261 | 0.278 | 0.278 | 0.276 | 0.276 | 0.276 | 0.276 | 0.277 |
| Mean | 0.274 | 0.226 | 0.246 | **0.275** | 0.264 | 0.261 | 0.267 | 0.26 | 0.268 | 0.244 |
| Std | 0.006 | 0.039 | 0.009 | **0.002** | 0.007 | 0.009 | 0.006 | 0.018 | 0.005 | 0.021 |
| Cv | 0.021 | 0.174 | 0.037 | **0.009** | 0.025 | 0.036 | 0.022 | 0.071 | 0.018 | 0.087 |
| RMSE | Min | 12.667 | 12.828 | 12.818 | **12.652** | 12.653 | 12.687 | 12.684 | 12.702 | 12.711 | 12.681 |
| Max | 12.802 | 13.994 | 13.081 | **12.737** | 12.97 | 12.931 | 12.826 | 13.187 | 12.831 | 13.245 |
| Mean | 12.709 | 13.138 | 12.959 | **12.692** | 12.8 | 12.816 | 12.763 | 12.837 | 12.758 | 12.962 |
| Std | 0.04 | 0.345 | 0.09 | **0.029** | 0.088 | 0.083 | 0.054 | 0.169 | 0.038 | 0.184 |
| Cv | 0.003 | 0.026 | 0.007 | **0.002** | 0.007 | 0.006 | 0.004 | 0.013 | 0.003 | 0.014 |
| MAE | Min | 7.77 | 7.944 | 8.008 | 7.749 | **7.329** | 7.818 | 7.825 | 7.593 | 7.789 | 7.794 |
| Max | 8.027 | 9.009 | 8.429 | 7.937 | 8.283 | 7.989 | **7.933** | 8.475 | 7.998 | 8.11 |
| Mean | 7.899 | 8.344 | 8.183 | **7.814** | 7.817 | 7.882 | 7.889 | 8.005 | 7.894 | 7.936 |
| Std | 0.084 | 0.296 | 0.131 | 0.061 | 0.289 | 0.051 | **0.042** | 0.291 | 0.065 | 0.115 |
| Cv | 0.011 | 0.035 | 0.016 | 0.008 | 0.037 | 0.007 | **0.005** | 0.036 | 0.008 | 0.014 |
| SMAPE | Min | 108.983 | 110.016 | 110.185 | 109.191 | **108.289** | 109.172 | 109.232 | 109.158 | 109.251 | 108.925 |
| Max | 110.125 | 113.247 | 111.472 | **109.603** | 110.379 | 109.662 | 109.848 | 111.451 | 109.853 | 110.041 |
| Mean | 109.656 | 111.248 | 110.776 | **109.341** | 109.289 | 109.415 | 109.55 | 110.184 | 109.5 | 109.559 |
| Std | 0.323 | 0.897 | 0.392 | **0.139** | 0.658 | 0.146 | 0.178 | 0.82 | 0.205 | 0.393 |
| Cv | 0.003 | 0.008 | 0.004 | **0.001** | 0.006 | **0.001** | 0.002 | 0.007 | 0.002 | 0.004 |

**Table 2: Bảng kết quả cho bộ dữ liệu weekly rainfall**

* 3 model cuối là của mình đề xuất: WDO- LSTM, MVO- LSTM, EO- LSTM

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Error | Statistics | MLP | RNN | LSTM | GA- LSTM | DE- LSTM | PSO- LSTM | WOA- LSTM | **WDO-LSTM** | **MVO- LSTM** | **EO- LSTM** |
| EV | Min | -0.069 | -0.057 | -0.103 | **0.205** | 0.19 | 0.13 | 0.189 | 0.144 | 0.134 | 0.072 |
| Max | 0.234 | 0.091 | 0.078 | **0.235** | 0.228 | 0.218 | 0.233 | 0.219 | 0.222 | 0.174 |
| Mean | 0.119 | 0.046 | 0.015 | **0.22** | 0.209 | 0.191 | 0.211 | 0.178 | 0.2 | 0.136 |
| Std | 0.113 | 0.054 | 0.06 | **0.01** | 0.014 | 0.026 | 0.012 | 0.027 | 0.025 | 0.03 |
| Cv | 0.952 | 1.164 | 4.004 | **0.046** | 0.067 | 0.135 | 0.056 | 0.15 | 0.127 | 0.22 |
| RMSE | Min | 7.632 | 8.337 | 8.523 | 7.585 | 7.393 | 7.616 | 7.579 | 7.79 | **7.53** | 7.773 |
| Max | 8.937 | 9.522 | 9.749 | **7.699** | 7.994 | 7.918 | 7.84 | 8.209 | 7.826 | 8.157 |
| Mean | 8.176 | 8.753 | 8.998 | **7.642** | 7.759 | 7.719 | 7.746 | 7.955 | 7.664 | 7.89 |
| Std | 0.481 | 0.407 | 0.41 | **0.044** | 0.194 | 0.105 | 0.075 | 0.128 | 0.102 | 0.125 |
| Cv | 0.059 | 0.046 | 0.046 | **0.006** | 0.025 | 0.014 | 0.01 | 0.016 | 0.013 | 0.016 |
| MAE | Min | 5.504 | 6.054 | 6.396 | 5.349 | **4.86** | 5.368 | 5.43 | 5.619 | 5.284 | 5.445 |
| Max | 6.416 | 7.578 | 7.793 | **5.59** | 6.023 | 5.678 | 5.775 | 6.259 | 5.663 | 5.777 |
| Mean | 5.955 | 6.706 | 6.989 | 5.475 | 5.581 | 5.511 | 5.617 | 5.84 | **5.465** | 5.609 |
| Std | 0.345 | 0.476 | 0.451 | **0.081** | 0.374 | 0.109 | 0.101 | 0.206 | 0.136 | 0.104 |
| Cv | 0.058 | 0.071 | 0.065 | **0.015** | 0.067 | 0.02 | 0.018 | 0.035 | 0.025 | 0.018 |
| SMAPE | Min | 75.417 | 78.841 | 81.258 | 74.297 | **70.002** | 74.193 | 74.624 | 75.917 | 73.445 | 74.787 |
| Max | 81.816 | 88.579 | 89.739 | **76.13** | 79.249 | 76.831 | 77.181 | 80.718 | 77.529 | 78.365 |
| Mean | 78.311 | 83.33 | 85.081 | **75.245** | 75.731 | 75.472 | 76.112 | 77.704 | 75.271 | 76.693 |
| Std | 2.074 | 2.956 | 2.709 | **0.646** | 2.951 | 0.826 | 0.761 | 1.522 | 1.272 | 1.288 |
| Cv | 0.026 | 0.035 | 0.032 | **0.009** | 0.039 | 0.011 | 0.01 | 0.02 | 0.017 | 0.017 |