***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 | 0.121 | 0.018 | 0.041 | 0.139 | 0.005 | 0.137 | 0.122 | **0.141** | 0.122 | 0.138 |
| Max | **0.171** | 0.101 | 0.116 | 0.155 | 0.145 | 0.164 | 0.160 | 0.156 | 0.168 | 0.165 |
| Mean | **0.153** | 0.07 | 0.071 | 0.15 | 0.107 | 0.15 | 0.143 | 0.151 | 0.149 | **0.153** |
| Std | 0.013 | 0.029 | 0.026 | 0.005 | 0.037 | 0.01 | 0.013 | **0.004** | 0.013 | 0.008 |
| Cv | 0.085 | 0.417 | 0.366 | 0.035 | 0.341 | 0.063 | 0.09 | **0.028** | 0.085 | 0.053 |
| RMSE | Min | **13.487** | 14.13 | 14 | 13.704 | 13.847 | 13.632 | 13.583 | 13.689 | 13.574 | 13.624 |
| Max | 14.11 | 15.047 | 14.604 | 13.841 | 14.848 | 13.842 | 13.976 | **13.823** | 13.946 | 13.856 |
| Mean | 13.778 | 14.371 | 14.359 | 13.746 | 14.104 | 13.744 | 13.823 | 13.75 | 13.749 | **13.73** |
| Std | 0.17 | 0.224 | 0.193 | 0.043 | 0.26 | 0.076 | 0.11 | 0.041 | 0.102 | **0.067** |
| Cv | 0.012 | 0.016 | 0.013 | 0.003 | 0.018 | 0.006 | 0.008 | 0.003 | 0.007 | **0.005** |
| MAE | Min | 8.227 | 8.482 | 8.485 | 8.514 | 8.085 | 8.447 | 8.386 | 8.426 | **8.017** | 8.387 |
| Max | 9.091 | 8.816 | 8.771 | 8.605 | 9.098 | 8.661 | 9.014 | 8.913 | 8.735 | **8.579** |
| Mean | 8.558 | 8.648 | 8.613 | 8.563 | 8.706 | 8.545 | 8.662 | 8.571 | **8.493** | 8.507 |
| Std | 0.278 | 0.084 | 0.093 | **0.025** | 0.313 | 0.063 | 0.151 | 0.141 | 0.129 | 0.049 |
| Cv | 0.032 | 0.01 | 0.011 | **0.003** | 0.036 | 0.007 | 0.017 | 0.016 | 0.015 | 0.006 |
| SMAPE | Min | **56.675** | 60.864 | 60.294 | 62.627 | 56.875 | 61.613 | 62.428 | 61.793 | 59.878 | 60.662 |
| Max | 66.359 | **62.939** | 63.217 | 64.315 | 70.062 | 65.515 | 66.195 | 66.315 | 64.754 | 64.193 |
| Mean | 62.233 | 61.955 | **61.557** | 63.601 | 64.113 | 63.403 | 64.165 | 63.289 | 62.418 | 62.123 |
| Std | 2.709 | 0.604 | 0.798 | **0.457** | 3.805 | 0.948 | 1.021 | 1.43 | 1.312 | 1.222 |
| Cv | 0.044 | **0.01** | 0.013 | 0.007 | 0.059 | 0.015 | 0.016 | 0.023 | 0.021 | 0.02 |

**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 | 0.042 | 0.116 | **0.123** | 0.065 | -0.076 | 0.008 | 0.053 | 0.031 | 0.014 | 0.036 |
| Max | 0.079 | **0.222** | 0.189 | 0.088 | 0.096 | 0.162 | 0.091 | 0.087 | 0.095 | 0.1 |
| Mean | 0.068 | **0.159** | 0.148 | 0.077 | 0.009 | 0.084 | 0.066 | 0.058 | 0.06 | 0.07 |
| Std | 0.009 | 0.03 | 0.022 | **0.007** | 0.058 | 0.05 | 0.023 | 0.017 | 0.022 | 0.023 |
| Cv | **0.138** | 0.189 | 0.146 | 0.088 | 6.548 | 0.593 | 0.184 | 0.294 | 0.364 | 0.325 |
| RMSE | Min | 9.897 | **9.048** | 9.24 | 9.846 | 9.715 | 9.414 | 9.845 | 9.832 | 9.81 | 9.759 |
| Max | 10.106 | 9.679 | **9.617** | 9.955 | 10.792 | 10.255 | 10.095 | 10.17 | 10.202 | 10.164 |
| Mean | 9.962 | **9.414** | 9.472 | 9.915 | 10.319 | 9.833 | 9.972 | 10.023 | 9.986 | 9.942 |
| Std | **0.052** | 0.173 | 0.123 | 0.032 | 0.341 | 0.259 | 0.061 | 0.103 | 0.12 | 0.133 |
| Cv | 0.005 | 0.018 | 0.013 | **0.003** | 0.033 | 0.026 | 0.006 | 0.01 | 0.012 | 0.013 |
| MAE | Min | 6.122 | **5.69** | 5.747 | 6.136 | 5.587 | 5.755 | 6.113 | 6.009 | 5.956 | 6.053 |
| Max | 6.32 | 6.179 | **6.018** | 6.243 | 7.528 | 6.622 | 6.431 | 6.501 | 6.474 | 6.61 |
| Mean | 6.202 | 5.882 | **5.877** | 6.207 | 6.479 | 6.18 | 6.256 | 6.256 | 6.189 | 6.237 |
| Std | 0.043 | 0.117 | 0.097 | **0.029** | 0.605 | 0.235 | 0.079 | 0.163 | 0.133 | 0.171 |
| Cv | **0.007** | 0.02 | 0.017 | 0.005 | 0.093 | 0.038 | 0.013 | 0.026 | 0.021 | 0.027 |
| SMAPE | Min | 48.071 | **42.963** | 43.516 | 48.383 | 40.055 | 44.184 | 46.423 | 44.193 | 45.748 | 46.022 |
| Max | 50.244 | 49.358 | **47.073** | 49.93 | 61.72 | 52.715 | 50.79 | 50.475 | 51.685 | 53.226 |
| Mean | 49.146 | **45.044** | 45.263 | 49.007 | 50.759 | 48.189 | 49.103 | 47.524 | 48.301 | 49.632 |
| Std | **0.55** | 1.701 | 1.253 | 0.446 | 7.098 | 2.351 | 1.22 | 1.817 | 1.473 | 2.127 |
| Cv | 0.011 | 0.038 | 0.028 | **0.009** | 0.14 | 0.049 | 0.025 | 0.038 | 0.031 | 0.043 |

**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 | 0.139 | 0.139 | 0.139 | -12794.3 | 0.121 | 0.111 | 0.134 | 0.147 | 0.1 | -0.012 |
| Max | 0.155 | 0.155 | 0.155 | -1074.69 | 0.178 | 0.19 | 0.169 | 0.164 | 0.194 | 0.147 |
| Mean | 0.15 | 0.15 | 0.15 | -2805.67 | 0.15 | 0.158 | 0.15 | 0.156 | 0.156 | 0.077 |
| Std | 0.005 | 0.005 | 0.005 | 3898.639 | 0.017 | 0.021 | 0.009 | 0.004 | 0.023 | 0.055 |
| Cv | 0.035 | 0.035 | 0.035 | -1.39 | 0.116 | 0.136 | 0.059 | 0.028 | 0.145 | 0.716 |
| RMSE | Min | 0.139 | 0.139 | 0.139 | 1416.495 | 13.487 | 13.434 | 13.623 | 13.601 | 13.368 | 13.764 |
| Max | 0.155 | 0.155 | 0.155 | 1727.342 | 14.11 | 14.024 | 13.96 | 13.798 | 14.207 | 14.987 |
| Mean | 0.15 | 0.15 | 0.15 | 1547.51 | 13.778 | 13.69 | 13.78 | 13.722 | 13.721 | 14.32 |
| Std | 0.005 | 0.005 | 0.005 | 92.827 | 0.17 | 0.165 | 0.093 | 0.051 | 0.197 | 0.43 |
| Cv | 0.035 | 0.035 | 0.035 | 0.06 | 0.012 | 0.012 | 0.007 | 0.004 | 0.014 | 0.03 |
| MAE | Min | 0.139 | 0.139 | 0.139 | 392.469 | 8.039 | 8.323 | 8.497 | 8.185 | 8.166 | 8.405 |
| Max | 0.155 | 0.155 | 0.155 | 1567.005 | 9.135 | 8.714 | 9.208 | 8.931 | 8.927 | 8.881 |
| Mean | 0.15 | 0.15 | 0.15 | 1288.067 | 8.561 | 8.5 | 8.641 | 8.585 | 8.584 | 8.634 |
| Std | 0.005 | 0.005 | 0.005 | 367.193 | 0.335 | 0.124 | 0.209 | 0.209 | 0.21 | 0.131 |
| Cv | 0.035 | 0.035 | 0.035 | 0.285 | 0.039 | 0.015 | 0.024 | 0.024 | 0.024 | 0.015 |
| SMAPE | Min | 0.139 | 0.139 | 0.139 | 194.924 | 57.549 | 59.962 | 61.495 | 58.999 | 58.695 | 58.958 |
| Max | 0.155 | 0.155 | 0.155 | 197.553 | 67.789 | 62.82 | 68.827 | 66.156 | 64.728 | 62.858 |
| Mean | 0.15 | 0.15 | 0.15 | 196.862 | 61.961 | 61.45 | 62.919 | 62.742 | 62.178 | 60.933 |
| Std | 0.005 | 0.005 | 0.005 | 0.8 | 3.075 | 0.884 | 2.157 | 2.105 | 1.716 | 0.935 |
| Cv | 0.035 | 0.035 | 0.035 | 0.004 | 0.05 | 0.014 | 0.034 | 0.034 | 0.028 | 0.015 |

**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 | 0.042 | 0.116 | 0.123 | -14074.2 | 0.019 | 0.008 | 0.014 | -0.003 | 0.017 | -3.682 |
| Max | 0.079 | 0.222 | 0.189 | -190.037 | 0.128 | 0.162 | 0.081 | 0.063 | 0.164 | 0.196 |
| Mean | 0.068 | 0.159 | 0.148 | -3729.81 | 0.063 | 0.084 | 0.044 | 0.034 | 0.113 | -0.268 |
| Std | 0.009 | 0.03 | 0.022 | 4786.328 | 0.029 | 0.05 | 0.023 | 0.016 | 0.04 | 0.964 |
| Cv | 0.138 | 0.189 | 0.146 | -1.283 | 0.457 | 0.593 | 0.524 | 0.485 | 0.35 | -3.589 |
| RMSE | Min | 9.897 | 9.048 | 9.24 | 425.76 | 9.536 | 9.414 | 9.832 | 10.004 | 9.341 | 9.208 |
| Max | 10.106 | 9.679 | 9.617 | 1255.785 | 10.356 | 10.255 | 10.266 | 10.354 | 10.126 | 22.278 |
| Mean | 9.962 | 9.414 | 9.472 | 1053.178 | 9.962 | 9.833 | 10.08 | 10.173 | 9.673 | 11.143 |
| Std | 0.052 | 0.173 | 0.123 | 187.789 | 0.196 | 0.259 | 0.145 | 0.109 | 0.206 | 3.22 |
| Cv | 0.005 | 0.018 | 0.013 | 0.178 | 0.02 | 0.026 | 0.014 | 0.011 | 0.021 | 0.289 |
| MAE | Min | 6.122 | 5.69 | 5.747 | 305.382 | 5.52 | 5.755 | 6.04 | 6.124 | 5.381 | 5.507 |
| Max | 6.32 | 6.179 | 6.018 | 1068.312 | 6.907 | 6.622 | 6.46 | 6.638 | 6.387 | 8.088 |
| Mean | 6.202 | 5.882 | 5.877 | 817.915 | 6.219 | 6.18 | 6.314 | 6.425 | 5.961 | 6.252 |
| Std | 0.043 | 0.117 | 0.097 | 299.965 | 0.314 | 0.235 | 0.135 | 0.158 | 0.27 | 0.613 |
| Cv | 0.007 | 0.02 | 0.017 | 0.367 | 0.05 | 0.038 | 0.021 | 0.025 | 0.045 | 0.098 |
| SMAPE | Min | 48.071 | 42.963 | 43.516 | 178.035 | 40.439 | 44.184 | 46.999 | 46.129 | 41.974 | 39.144 |
| Max | 50.244 | 49.358 | 47.073 | 197.924 | 55.128 | 52.715 | 49.804 | 52.453 | 52.037 | 50.728 |
| Mean | 49.146 | 45.044 | 45.263 | 193.526 | 47.997 | 48.189 | 48.464 | 49.556 | 45.317 | 44.776 |
| Std | 0.55 | 1.701 | 1.253 | 7.557 | 3.421 | 2.351 | 0.889 | 1.906 | 3.013 | 3.086 |
| Cv | 0.011 | 0.038 | 0.028 | 0.039 | 0.071 | 0.049 | 0.018 | 0.038 | 0.066 | 0.069 |