Water Resource Research

Supporting Information for

Hierarchical Temporal Scale Data-driven Reservoir Operation Modeling

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Text S1.

The Long-Short Term Memory (LSTM) computations are expressed as

$$
\begin{aligned}
i_t &= \sigma(W_{xi} \cdot x_t + W_{hi} \cdot h_{t-1} + b_i) \\
f_t &= \sigma(W_{xf} \cdot x_t + W_{hf} \cdot h_{t-1} + b_f) \\
g_t &= tanh\,(W_{xg} \cdot x_t + W_{hg} \cdot h_{t-1} + b_g) \\
o_t &= \sigma(W_{xo} \cdot x_t + W_{ho} \cdot h_{t-1} + b_o) \\
c_t &= f_t \odot c_{t-1} + i_t \odot g_t \\
h_t &= o_t \odot tanh\,(c_t)
\end{aligned}
$$

where W_{xi}, W_{xf}, W_{xg} and W_{xo} are learnable weights of inputs x_t, W_{hi}, W_{hf}, W_{hg} and W_{ho} are learnable weights of the previous hidden states h_t, and b_i, b_f, b_o and b_g are biases of the four gates, respectively. means sigmoid function, tanh is hyperbolic tangent function, and represents element-wise multiplication.

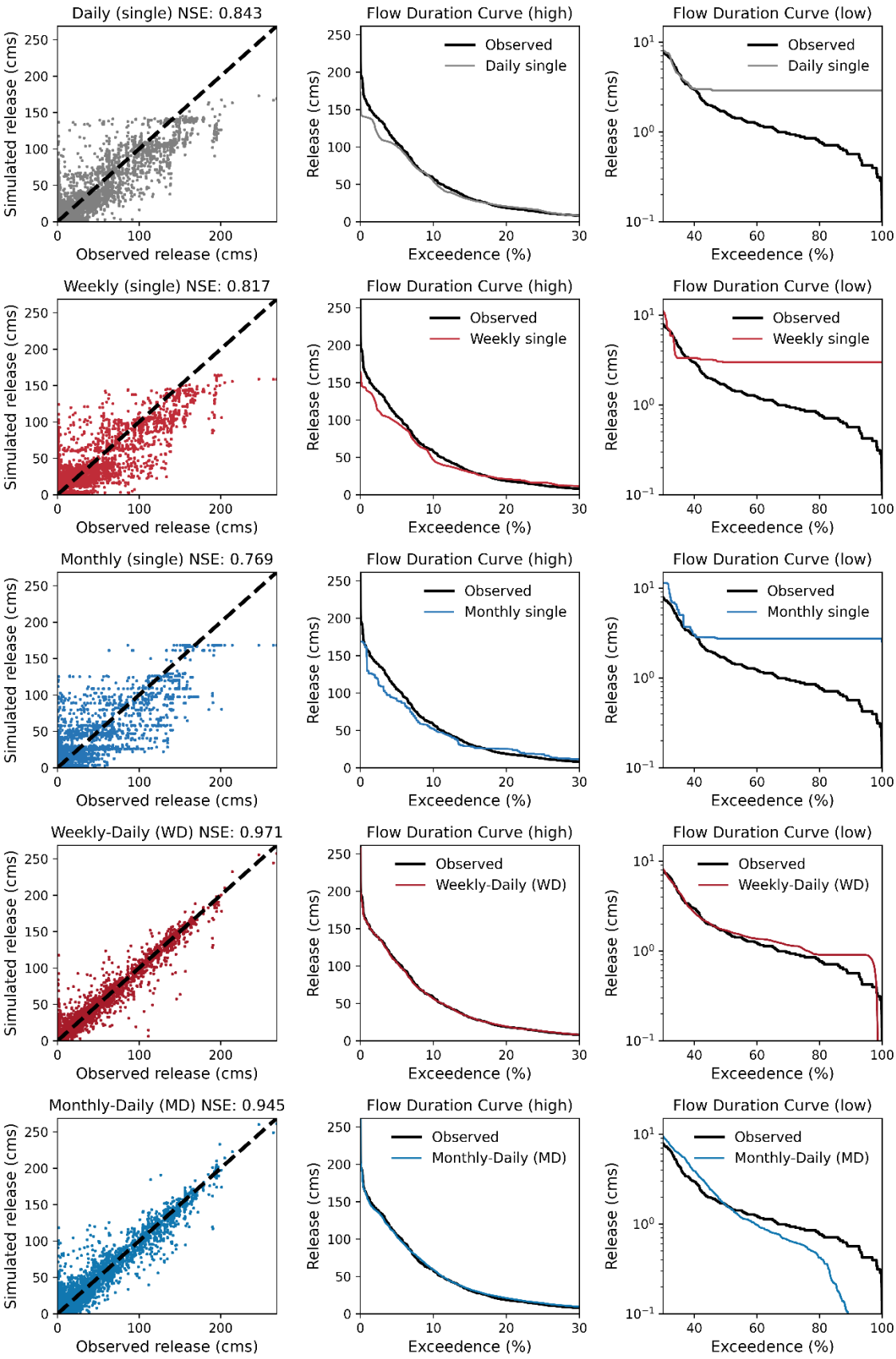
Daily (single) NSE: 0.843
Simulated release (cms)
Observed release (cms)
Flow Duration Curve (high)
Observed
Daily single
Release (cms)
Exceedence (%)
Flow Duration Curve (low)
Observed
Daily single
Release (cms)
Exceedence (%)
Weekly (single) NSE: 0.817
Simulated release (cms)
Observed release (cms)
Flow Duration Curve (high)
Observed
Weekly single
Release (cms)
Exceedence (%)
Flow Duration Curve (low)
Observed
Weekly single
Release (cms)
Exceedence (%)
Monthly (single) NSE: 0.769
Simulated release (cms)
Observed release (cms)
Flow Duration Curve (high)
Observed
Monthly single
Release (cms)
Exceedence (%)
Flow Duration Curve (low)
Observed
Monthly single
Release (cms)
Exceedence (%)
Weekly-Daily (WD) NSE: 0.971
Simulated release (cms)
Observed release (cms)
Flow Duration Curve (high)
Observed
Weekly-Daily (WD)
Release (cms)
Exceedence (%)
Flow Duration Curve (low)
Observed
Weekly-Daily (WD)
Release (cms)
Exceedence (%)
Monthly-Daily (MD) NSE: 0.945
Simulated release (cms)
Observed release (cms)
Flow Duration Curve (high)
Observed
Monthly-Daily (MD)
Release (cms)
Exceedence (%)
Flow Duration Curve (low)
Observed
Monthly-Daily (MD)
Release (cms)
Exceedence (%)

Figure S1. Model performances of Belton Lake (TX00002). The subfigures in the first column show that Daily/Weekly/Monthly single models that are constructed on a single time scale work not so well, particularly for the high flow with the exceedance probability less than 30% (subfigures in the second column), while Weekly-Daily (WD) and Monthly-Daily (MD) hierarchical models improve the performances, both for the high flow and low flow.

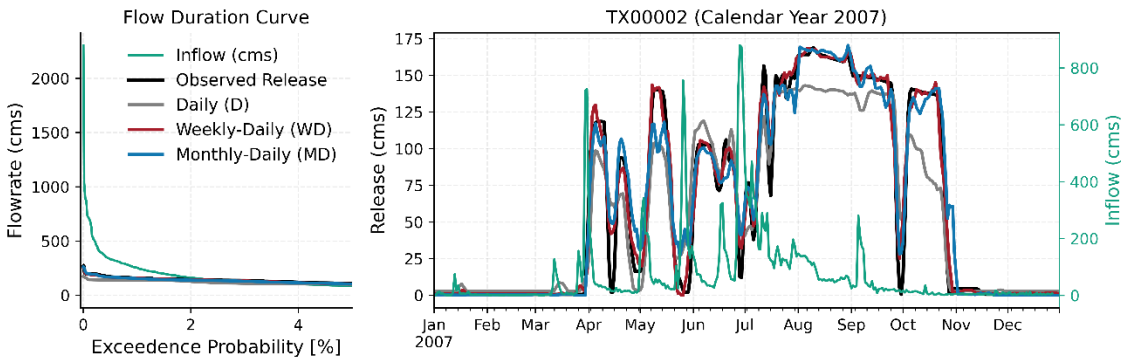

Figure S2. Inflow, observed release, release simulated by Daily (D), Weekly-Daily (WD) and Monthly-Daily (MD) models of Belton Lake (TX00002) shown in Flow Duration Curve and hydrograph during the calendar year 2007. It illustrates that data-driven models capture the pattern how operators response to extreme flood events, and hierarchical time scale model (WD and MD) could simulate the release schemes better.