A Multiscale Post-Processing Technique for Short-to-Long-Range Ensemble Streamflow Prediction

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Abstract

- Streamflow prediction is subject to large input and hydrologic uncertainties.
- The Hydrologic Ensemble Forecast Service (HEFS) is used by the National Weather Service (NWS) River Forecast Centers (RFCs) to generate ensemble streamflow forecast.
- In HEFS, the Meteorological Ensemble Forecast Processor (MEFP_ and the Ensemble Post-Processor (EnsPost) model input and hydrologic uncertainties, respectively.
- Here we describe a novel multi-scale post-processor for ensemble streamflow prediction, MS-EnsPost, and the evaluation results.
- MS-EnsPost employs magnitude-dependent bias correction, multi-scale regression and parsimonious error modeling to utilize skill available over a range of time scales and to reduce data requirements.

Methodology

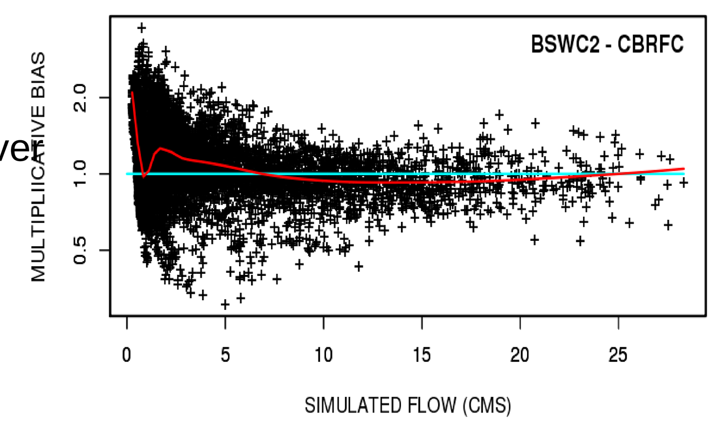
- **Magnitude-dependent bias correction**

$$\beta_{k,i} = \frac{a^o_{k,(j)}}{a^s_{k,(j)}}, i \in [(j_k - 1)L_k + 1, j_k L_k \quad (1)$$

$\beta_{k,i}$: bias for simulated flow at the k-th aggregation scale

$a^o_{k,(j)}$: sorted observed flow aggregated over the j-th time window of the k-th time scale

$a^s_{k,(j)}$: sorted simulated flow aggregated over the j-th time window of the k-th time scale



- **Multiscale regression**

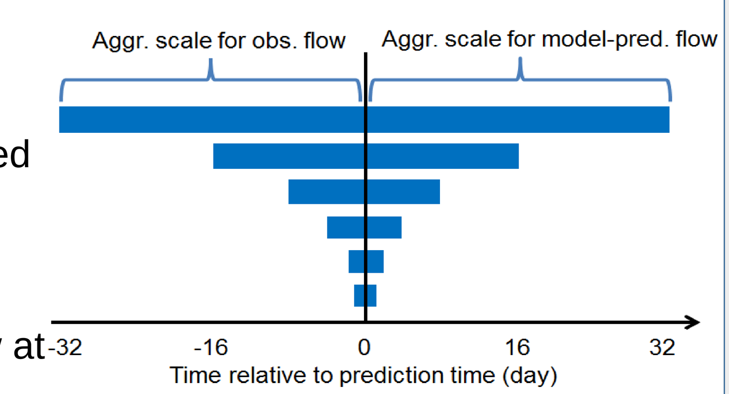
$$a^p_{k,1} = \varpi_k a^o_{k,0} + (1 - \varpi_k) a^b_{k,1}, k = 1, \ldots, M \quad (2)$$

$a^p_{k,1}$: time-aggregated predicted flow at a time step ahead

ϖ_k: optimal weight for the time-aggregated observed flow at the k-th scale

$a^o_{k,0}$: time-aggregated observed flow at the current time step

$a^b_{k,1}$: time-aggregated bias-corrected flow at a time step ahead



- **Error modeling & ensemble generation**

$$\varepsilon^t_i = q^{to}_i - q^{tp}_i = \frac{(q^o_i)^\lambda - 1}{\lambda} - \frac{(q^p_i)^\lambda - 1}{\lambda} = \frac{(q^o_i)^\lambda - (q^p_i)^\lambda}{\lambda}, \varepsilon^t_i \geq -(q^p_i)^\lambda/\lambda \quad (3)$$

$$\varepsilon^t_i(\omega) = \mu_{\varepsilon^t_i} + s_{\varepsilon^t_i}\Phi^{-1}[\Phi(z^t_i) + U(\omega)\{1 - \Phi(z^t_i)\}] \quad (4)$$

$\varepsilon^t_i(\omega)$: ensemble realization of error at lead time i

q_i^{to}: Box-Cox transformed observed flow, q_i^{ts}: Box-Cox transformed observed flow

$\mu_{\varepsilon^t_i}$: sample mean of ε^t_i, $s_{\varepsilon^t_i}$: sample variance of ε^t_i

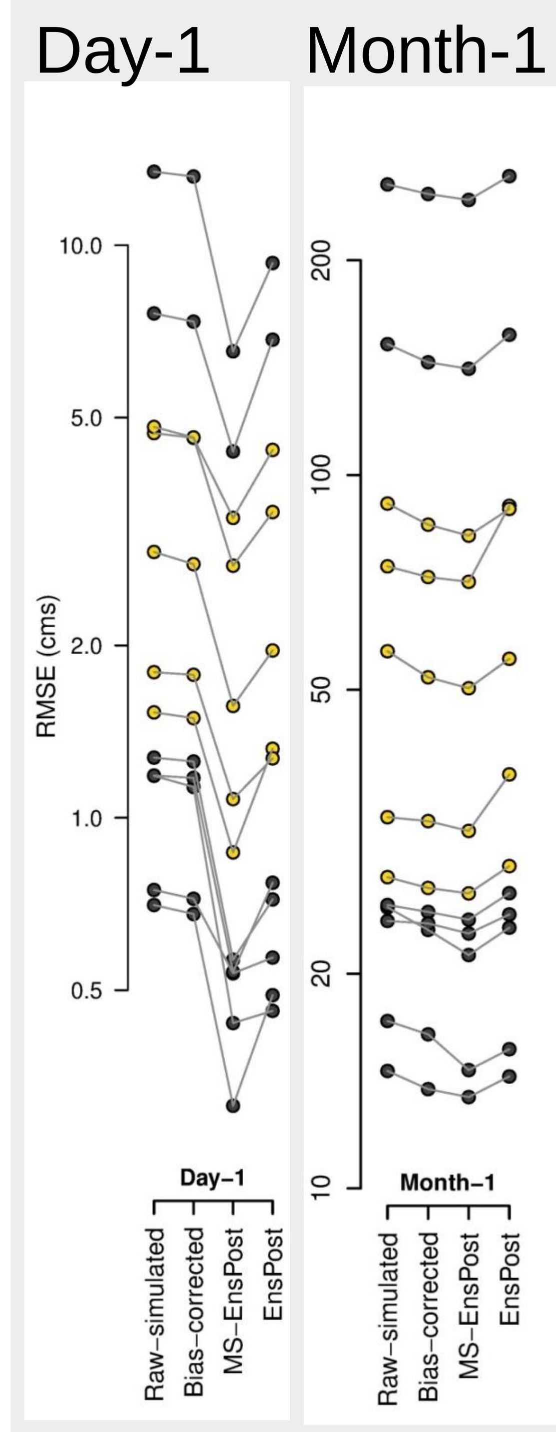
$U(\omega)$: sample realization of the [0,1] uniform random variable

$\Phi(\,)$: standard normal cumulative distribution function (CDF)

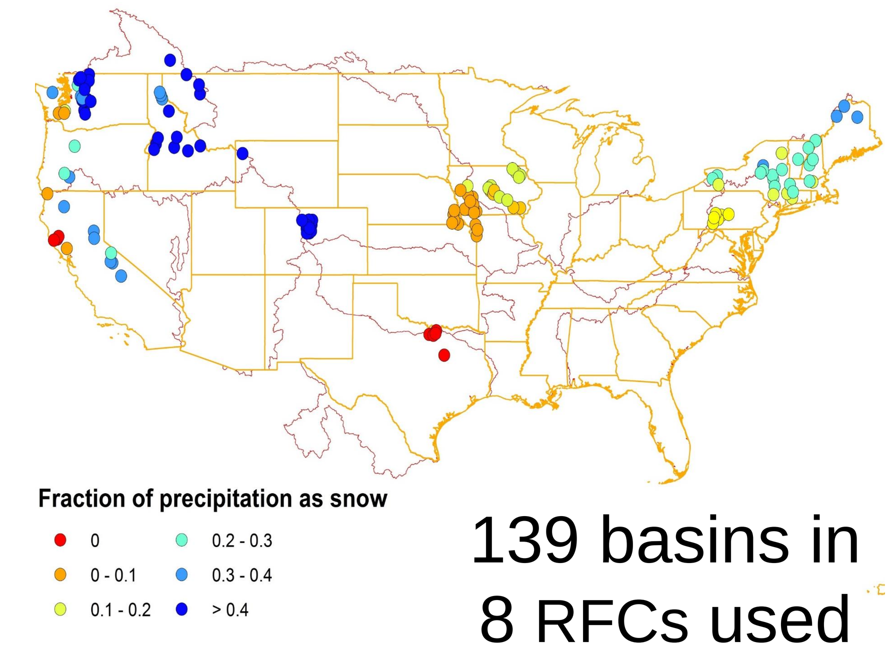
z^t_i: the normalized lower bound of ε^t_i

Evaluation results

CBRFC



Comparative evaluation

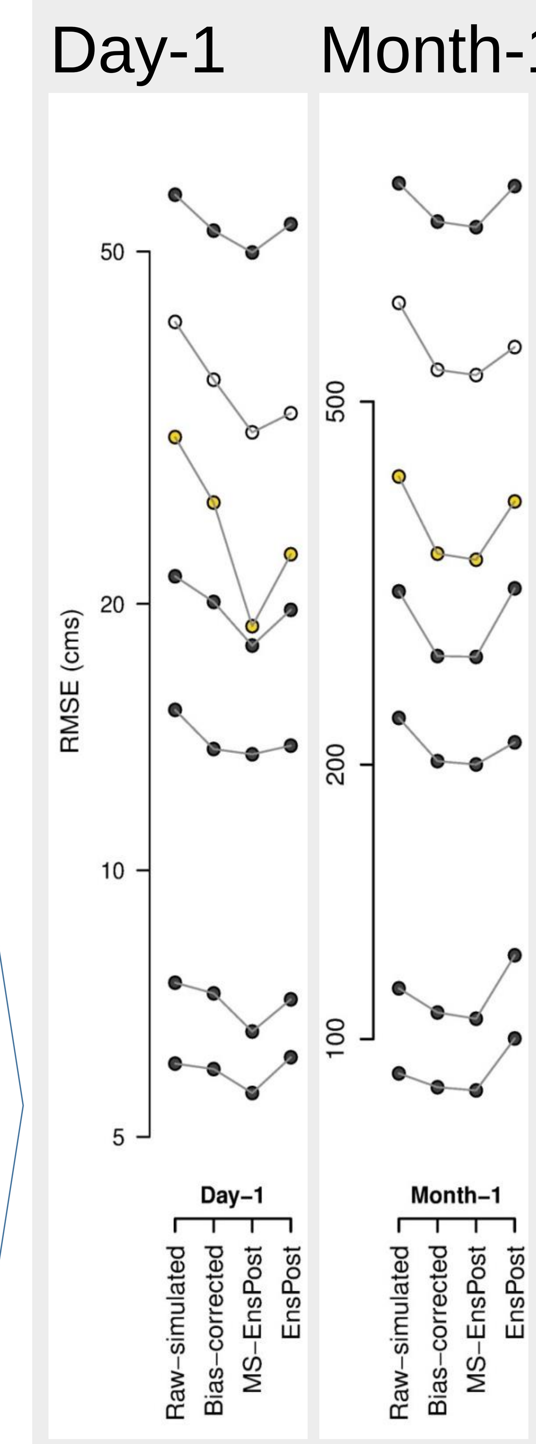


139 basins in 8 RFCs used

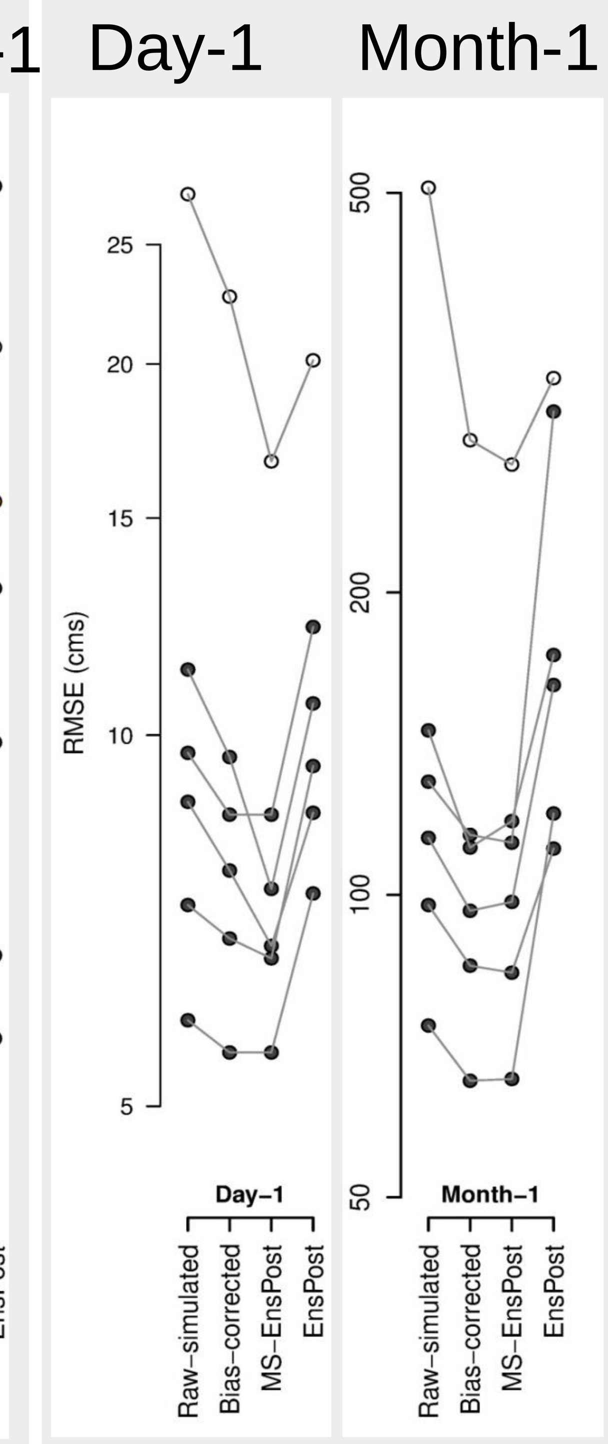
RMSE comparison of Day-1 and Month-1 predictions among:

1) no post-processing,
2) bias correction only,
3) MS-EnsPost (i.e., bias correction and multiscale regression), and
4) EnsPost

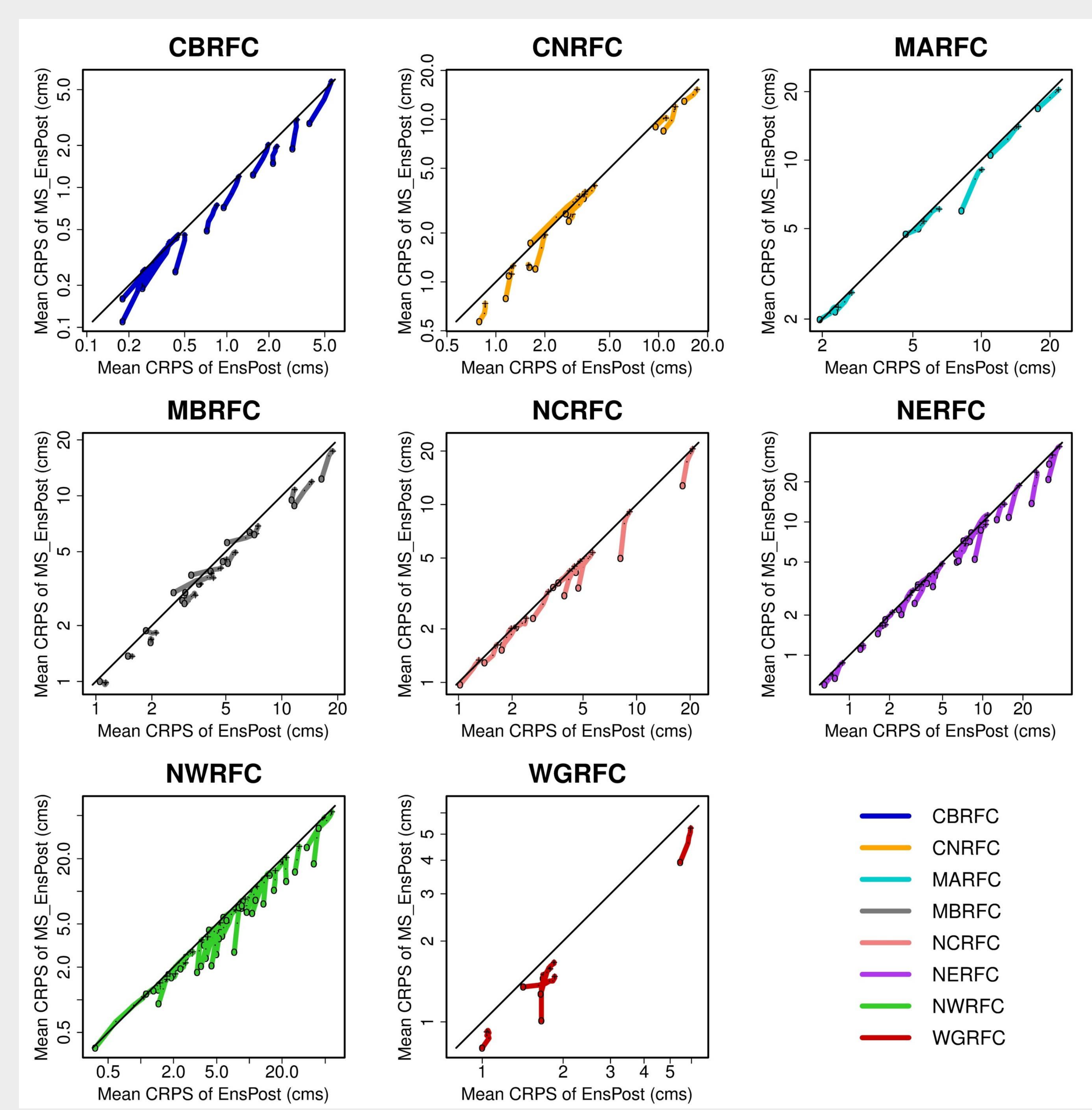
MARFC



WGRFC

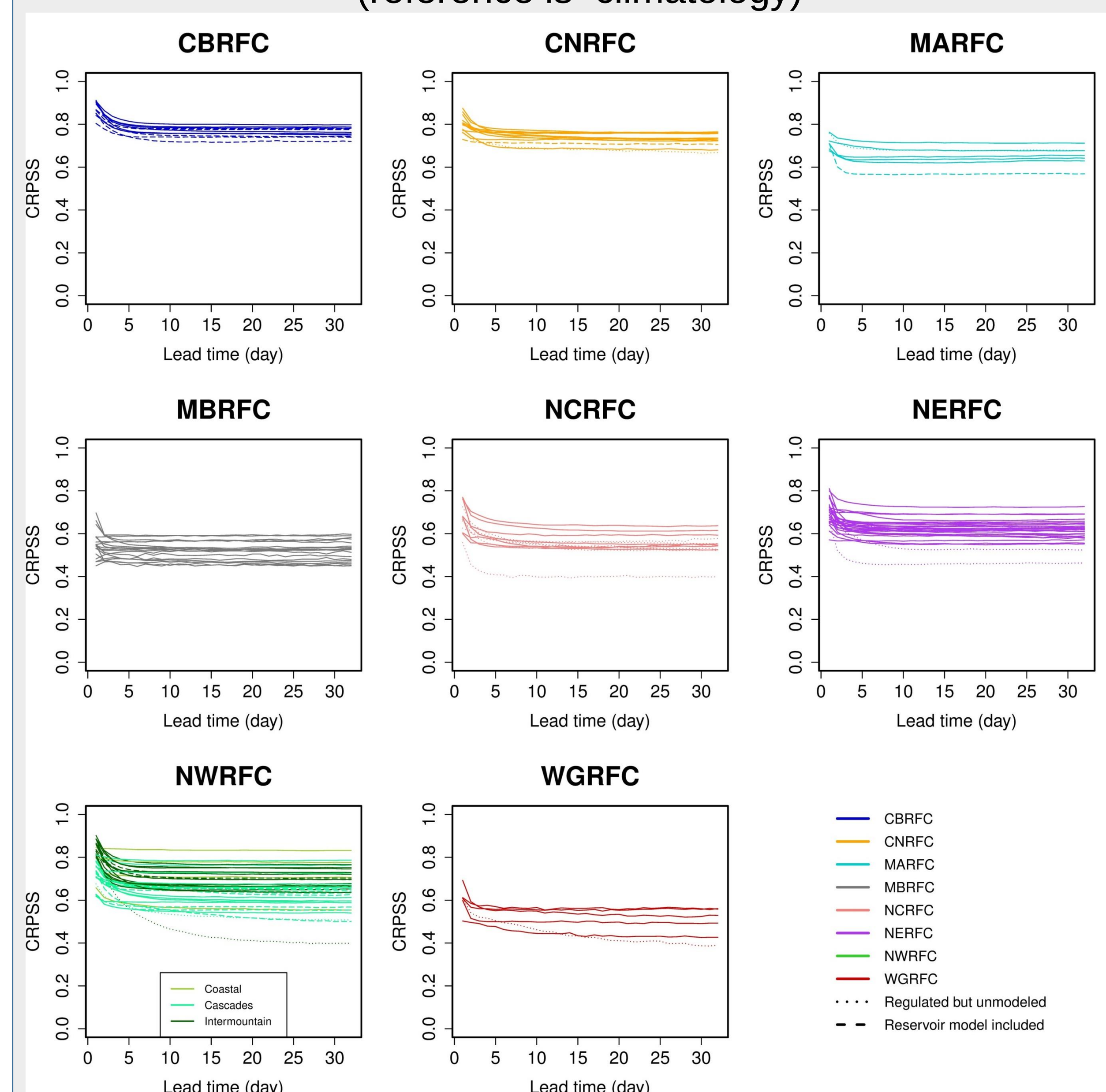


Continuous Ranked Probability Score of Day-1 to -7 mean daily flow predictions: MS-EnsPost vs. EnsPost



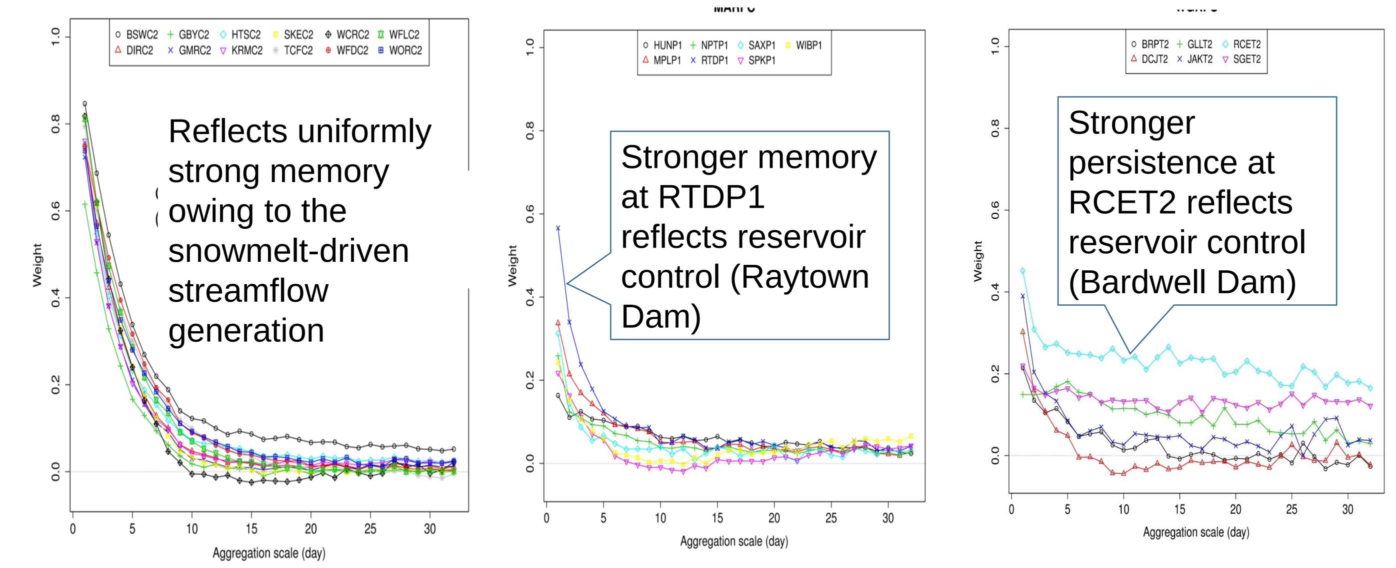
Continuous Ranked Probability Skill Score of MS-EnsPost mean daily flow predictions

(reference is climatology)



Multiscale regression weights

The weight for the aggregated observed flow, ϖ_k, k=1,…,M, in Eq. (2) reflects scale-dependent predictability of the hydrologic system.



Conclusions and research recommendations

- MS-EnsPost reduces the root mean square error of Day-1 to -7 predictions with EnsPost of mean daily flow by 5 to 68 percent, and the Continuous Ranked . For most basins, the improvement is due to both bias correction and multiscale regression.
- MS-EnsPost reduces the mean Continuous Ranked Probability Score of Day-1 to -7 predictions with EnsPost of mean daily flow by 2 to 62 percent.
- Examination of the mean Continuous Ranked Probability Skill Scores (CRPSS) indicates that, for most basins, the improvement by MS-EnsPost is due to both magnitude-dependent bias correction and exhaustive utilization of hydrologic memory through multiscale regression.
- Additional efforts are needed to render the errors closer to truncated normal and homoscedastic through an improved and more objective process, to improve the temporal dependence modeling of the error for improved prediction of time-integrated flow, and to assess performance under reduced data following rigorous identification of nonstationarity.

References

Alizadeh, B., Limon, R.A., Seo, D.J., Lee, H. and Brown, J., 2019. Multiscale Post-Processor for Ensemble Streamflow Prediction for Short-to-Long Ranges. Journal of Hydrometeorology.

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