

Reply to Referee comment 2

Thank you for your thorough review and valuable comments. Below are our detailed replies to each of your comments. We believe that the planned revisions will significantly enhance the quality and readability of our manuscript.

Comment: Given the elevation and complex topography of the study area, it would be useful to have a visualization of the gage density of the CGDPA observational product in this region. Are the authors concerned about the accuracy of the GCDPA product in gage sparse regions of the basin? Additionally, the mismatch between the GBEHM resolution (8-km) and the meteorological forcing (25-km) may be one source of error in streamflow forecasts.

Reply: We sincerely appreciate these insightful comments. Regarding the request for a visualization of gauge density, we would like to direct readers to the previous work by Shen and Xiong (2016), which provides exhaustive spatial distribution maps and station data for the over 2,400 national gauges utilized in the CGDPA product. While we acknowledge inherent uncertainties in high-elevation and gauge-sparse regions, CGDPA remains a highly reliable dataset available for China and has been widely used as reference dataset in the literature (Shaowei et al., 2022; Lu and Yong, 2020; Wei et al., 2019). Furthermore, we fully agree that the spatial mismatch between the 25-km forcing and the 8-km hydrological grid is a non-negligible source of error, as it may smooth out localized precipitation details. We will incorporate these data uncertainty and scale mismatch issues into the limitations section.

References

- Lu, D. and Yong, B.: A preliminary assessment of the gauge-adjusted near-real-time GSMaP precipitation estimate over Mainland China, *Remote Sens.*, 12, 141, <https://doi.org/10.3390/rs12010141>, 2020.
- Shaowei, N., Jie, W., Juliang, J., Xiaoyan, X., Yuliang, Z., Fan, S., and Linlin, Z.: Comprehensive evaluation of satellite-derived precipitation products considering spatial distribution difference of daily precipitation over eastern China, *J. Hydrol. Reg. Stud.*, 44, 101242, <https://doi.org/10.1016/j.ejrh.2022.101242>, 2022.
- Shen, Y. and Xiong, A.: Validation and comparison of a new gauge-based precipitation analysis over mainland China, *Int. J. Climatol.*, 36, 252-265, <https://doi.org/10.1002/joc.4341>, 2016.
- Wei, L., Jiang, S., Ren, L., Yuan, F., and Zhang, L.: Performance of two long-term satellite-based and GPCC 8.0 precipitation products for drought monitoring over the Yellow River Basin in China, *Sustainability*, 11, 4969, <https://doi.org/10.3390/su11184969>, 2019.

Comment: The precipitation bias correction is clearly impactful; this manuscript would benefit from a greater understanding of what relationships the CNN is capturing better than traditional statistical models.

Reply: Thank you for this specific comment. Unlike traditional point-to-point statistical models (e.g., quantile mapping), our CNN model excels by capturing two key relationships. First, it extracts spatial dependencies from surrounding atmospheric conditions using a 9×9 grid neighborhood. Second, it models the complex non-linear interactions between 20 multi-level meteorological predictors and local precipitation. We will expand the discussion on these specific mechanisms in the revised manuscript to provide better interpretability.

Comment: The following step from Line 230 is unclear and could benefit from further explanation or a figure: “the model generates a deterministic forecast by constructing a large-scale pseudo-ensemble from the predicted CSG distribution at equal quantiles and calculating the ensemble mean.”

Reply: We sincerely appreciate the reviewer for pointing out this ambiguity. The step is essentially a quantile-based discretization of distribution and the detailed procedure is as follows:

1. Based on the three parameters (γ, μ, σ) output by the CNN, the cumulative distribution function (CDF) of the predicted CSG distribution is established.
2. We discretize this CDF into N equal probability intervals (in this study, we set $N = 10000$, corresponding to percentiles from 0.00005 to 0.99995).
3. We apply the inverse CDF (quantile function) at each probability point to extract 10000 discrete precipitation values, thereby forming a "pseudo-ensemble" of 10000 members.
4. Finally, the arithmetic mean of this pseudo-ensemble is calculated to serve as the final deterministic precipitation forecast.

This sampling approach integrates low-probability extreme values from the heavy tail into the ensemble mean to mitigate the smoothing effect. We will expand the explanation and schematic of this procedure in the supplement to improve clarity.