# Response to the referee #2 of the research article egusphere-2024-2962: Skilful Seasonal Streamflow Forecasting Using a Fully Coupled Global Climate Model

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We thank the referee for the detailed review and feedback. We will prepare a revised manuscript addressing the comments. We have organized this reply document as follows:

- The referee comments are in black.
- Our responses are in blue.
- The paraphrases with additions/modifications proposed in the manuscript are in red.
- Figures prepared for the reply have the prefix "R", such as Figure R1.

## Revisions

1. Section 2.4: More explanation is needed here. Is streamflow bias correction applied only to the online models? If so, how is the comparison fair when offline models are not post-processed?

   We thank you for the opportunity to clarify this key point. The atmospheric quantities are not bias-corrected for any forecasting configuration. Meanwhile, during post-processing, the streamflow bias correction is applied to offline and online forecasts for consistent comparison. Accordingly, this point will be clarified in section 2.4 of the revised manuscript, as follows.

   Our study uses an online atmosphere-ocean-land-river coupled model, for which bias correcting the atmospheric forcing is irrelevant. Instead, we correct the streamflow forecast bias for each flow-gauge station using the Empirical Quantile Mapping method (EQM). To ensure consistent comparisons, we apply streamflow bias correction to both offline and online forecasts.

2. Section 3.1, Figure 3: Why do panels (c, f, i) all use percent mean bias (%) as the x-axis? This makes the figure difficult to interpret. The same issue applies to Figure 4.? Panels (c, f, i) correspond to percent mean bias (%), RMSE (mm/day) and ACC, respectively. We have corrected the horizontal labels in the revised manuscript's last column of Figures 3-4 (see the following reproduction of the reviewed figure for May initialisation).

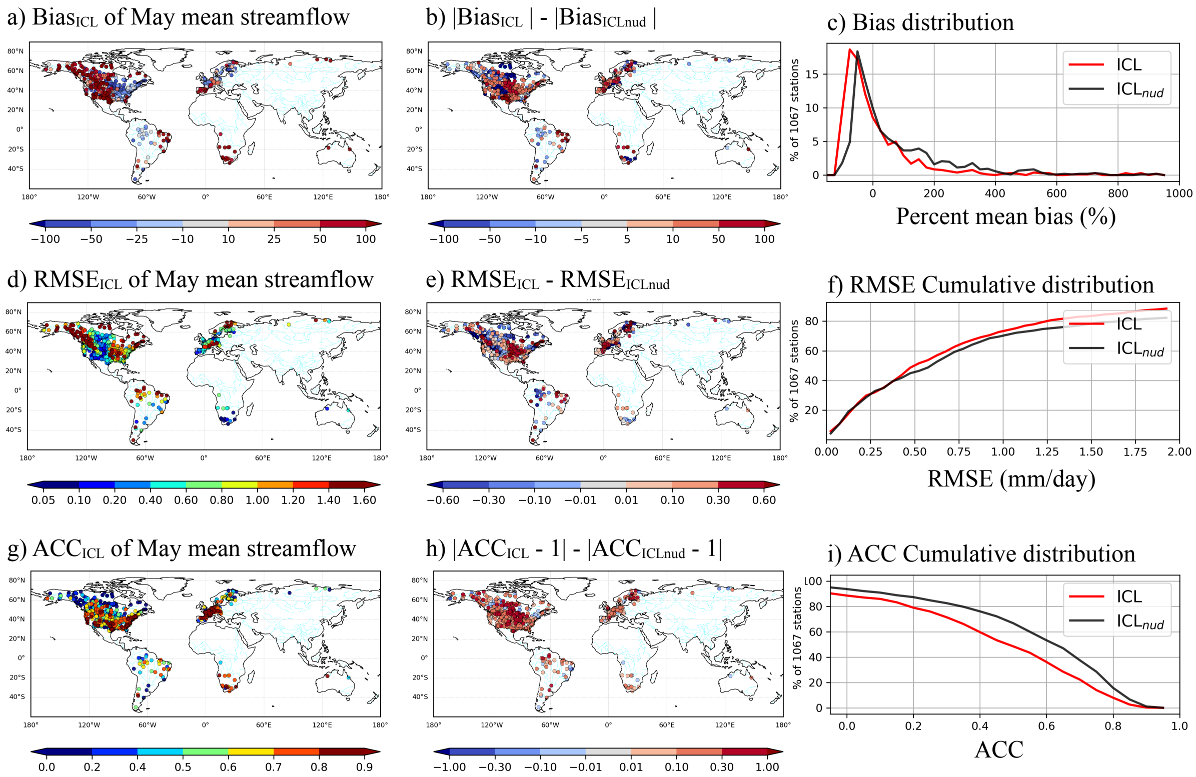


**Figure 3.** Comparison between May streamflow mean of initialisation run against the observed one over 1993-2017. Left column: ICL bias (a), root mean square error (mm/d) (d), and anomaly correlation (g). Middle column: difference with the ICL$_{nud}$ enhanced land initialisation bias (b), root mean square error (mm/d) (e), and anomaly correlation (h). Right column: distribution of bias for each experiment (c), accumulated distributions of the root mean square (f), and anomaly correlation (i).

3. Line 212: Clarify what is meant by "dryest regions" here. The same applies to Figure 4. We agree that the "dry region" concept was unclear in the referred statement. Based on the global aridity index (see Figure R1), we can better visualize our considerations about dry regions.

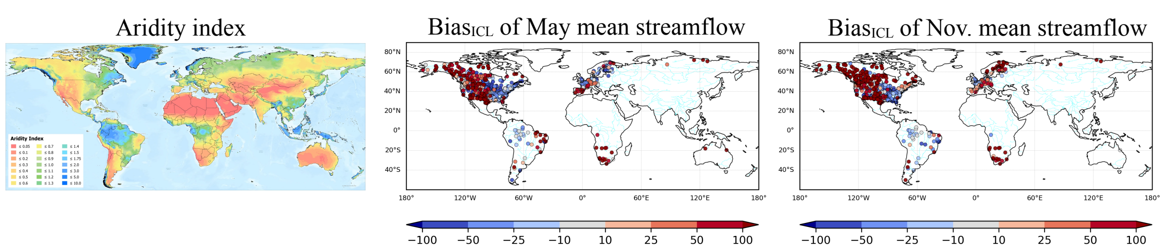


**Figure R1.** Global Aridity index comparison against May and November streamflow mean bias of initialisation runs. Left column: Aridity Index (Zomer et al., 2022). Middle column: ICL bias of May. Right column: ICL bias of November.

We propose the following modified paragraph to the original manuscript.

For May, the streamflow Bias of ICL tends to be positive in the dryest regions (Fig. 3a), particularly in western North America, southwestern South America, northeastern Brazil, southern Africa, Iberian peninsula and Australia.

This claim is less evident for November (Fig. 4a). Thus, we have removed the short sentence referring to dry regions without generating any disagreement or contradiction in the discussion, as follows.

The performance of the river initialisation in November (used for DJF forecasts) is presented in Fig. 4. $ICL_{nud}$ tends to reduce the mean bias of stations displaying a high positive bias in ICL ~~, more frequently located over dry regions.~~ (Figure 4a-b).

4. Line 213: The argument for this figure is not very clear to me. The current phrasing implies that the positive/negative bias directions remain unchanged from ICL to ICLnud, which is not necessarily the case. The reduction of negative bias refers to that some original blue-marked points in (a) got red points in (b), but as I understand, the figure (b) shows the difference in the absolute value of bias, meaning the ICLnud bias can be either negative or positive. While the claim that bias is reduced is still valid. Maybe try to rephrase the argument, and it would be useful to also show the bias of ICLnud, perhaps in an appendix. The bias frequency distribution in Figure 3c further supports our claim. We observed that the peak on the negative bias side (represented by the red curve) shifts toward a smaller bias for the $ICL_{nud}$ (black curve), indicating a decrease in negative bias. On the positive bias side, the black curve rises above the red curve, suggesting an increase in positive bias compared to the ICL. However, this change is observed in only a small percentage of stations, resulting in a minimal overall impact. To clarify this statement, we have rephrased it in the revised manuscript as follows:

   The higher concentration of red markers in Figure 3b indicates a reduction in bias from ICL to $ICL_{nud}$. This reduction is more pronounced for negative bias, as displayed by the shift of the negative peak towards zero bias in the frequency distribution shown in Figure 3c.

5. Lines 232-235: The description for locations is inconsistent, sometimes referring to latitude, sometimes to country names, which is difficult to follow. Also, the interpretations themselves sometime do not match with each other. For example, in Line 234, it is stated that Europe shows improved precipitation predictions, but the previous sentence states degradation in the north of 40°N. Similarly, Australia is within the range that is described as showing improved correlation as it is south of 20°S, but it shows degradation in the figure. In general, this figure is difficult to interpret. Consider either adding highlighted boxes on the plot to clearly mark the areas being discussed, or use a better way to specify the area in the text.

   We understand the difficulty caused by the inconsistency in the location description. Following the suggestions, we have included boxes indicating the discussed areas in the figures. Besides, the location description has been homogenised, as follows.

   A global view does not reveal marked changes in terms of ACC for the atmospheric predictions. However, from a continental to regional view, differences are noticeable. In boreal summer (Figure 5), enhanced initialisation $ICL_{nud}$ tends to increase precipitation correlation in the middle region of South America, including the Paraná River basin and southern Amazon basin (red box), with degradation in the northeast of Brazil, Australia, and some areas of North America and Asia on the north of $40°N$ (cyan boxes). Notably, Europe experiences improved precipitation predictions. Temperature predictions are less sensitive to the land initialisation in summer, but degradation is concentrated in higher latitudes (north of $40°N$ and south of $20°S$). In winter, regions with reduced performance for both precipitation and temperature predictions are primarily found in North Africa, Europe, and Asia (Figure 6).

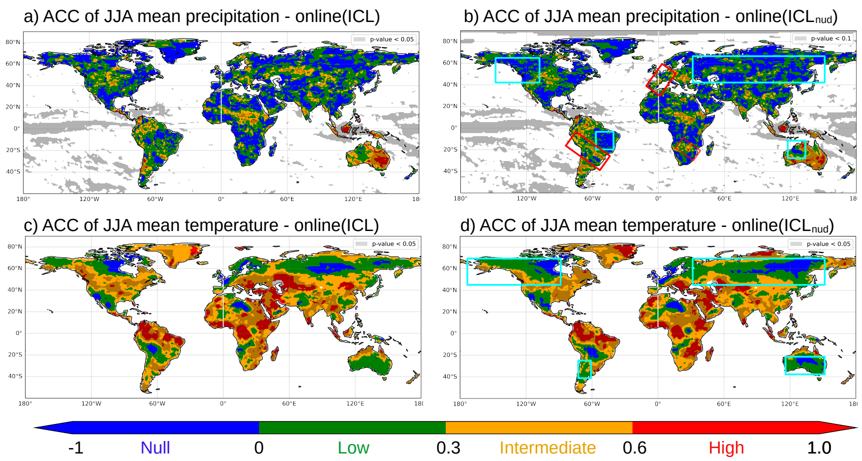


**Figure 5.** Comparison of Online_ICL and Online_ICL$_{nud}$ atmospheric forecasts for the anomalies correlation coefficient of the JJA 3-month mean precipitation (a and b) and temperature (c and d). Red (Cyan) boxes highlight regions with noticeable ACC increase (decrease).

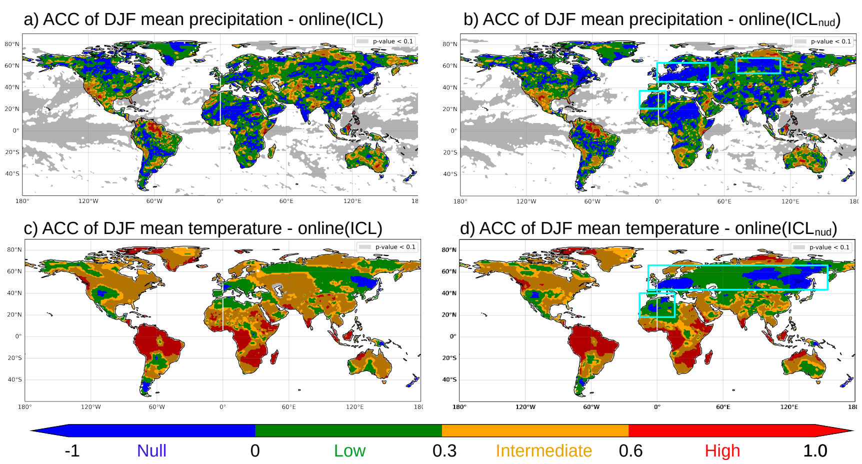


**Figure 6.** Comparison of Online_ICL and Online_ICL$_{nud}$ atmospheric forecasts for the anomalies correlation coefficient of the DJF 3-month mean precipitation (a and b) and temperature (c and d). Red (Cyan) boxes highlight regions with noticeable ACC increase (decrease).

6. Line 253: "From Online_ICLnud to Online_ICL, the ACC is slightly reduced, especially for basin outlets north of 40°N." Is this correct? It seems like the opposite may be true, please verify. This typo has been corrected, as follows.

   In addition, from Online_ICL to Online_ICL$_{nud}$, the ACC is slightly reduced, especially for basin outlets in the north of $40°N$.

7. Line 255, Figures 7: Are the online system results in this figure bias-corrected or not? Some explanation would help to understand. As stated in Section 2.4 (see reply to comment 1 of this revision) and in the caption of Figure 7, all streamflow forecasts are bias-corrected.

8. Figure 7: The red color is used to represent better performance, which is somehow difficult to remember. Consider either adjusting the color scheme or adding a note in the legend to show the optimal side.

The optimal value and explanation of all the scores computed and evaluated in our study are contained in Table 3 of the manuscript. However, following your suggestion, we have reinforced the optimal side of the anomaly correlation coefficient presented in Figure 7.

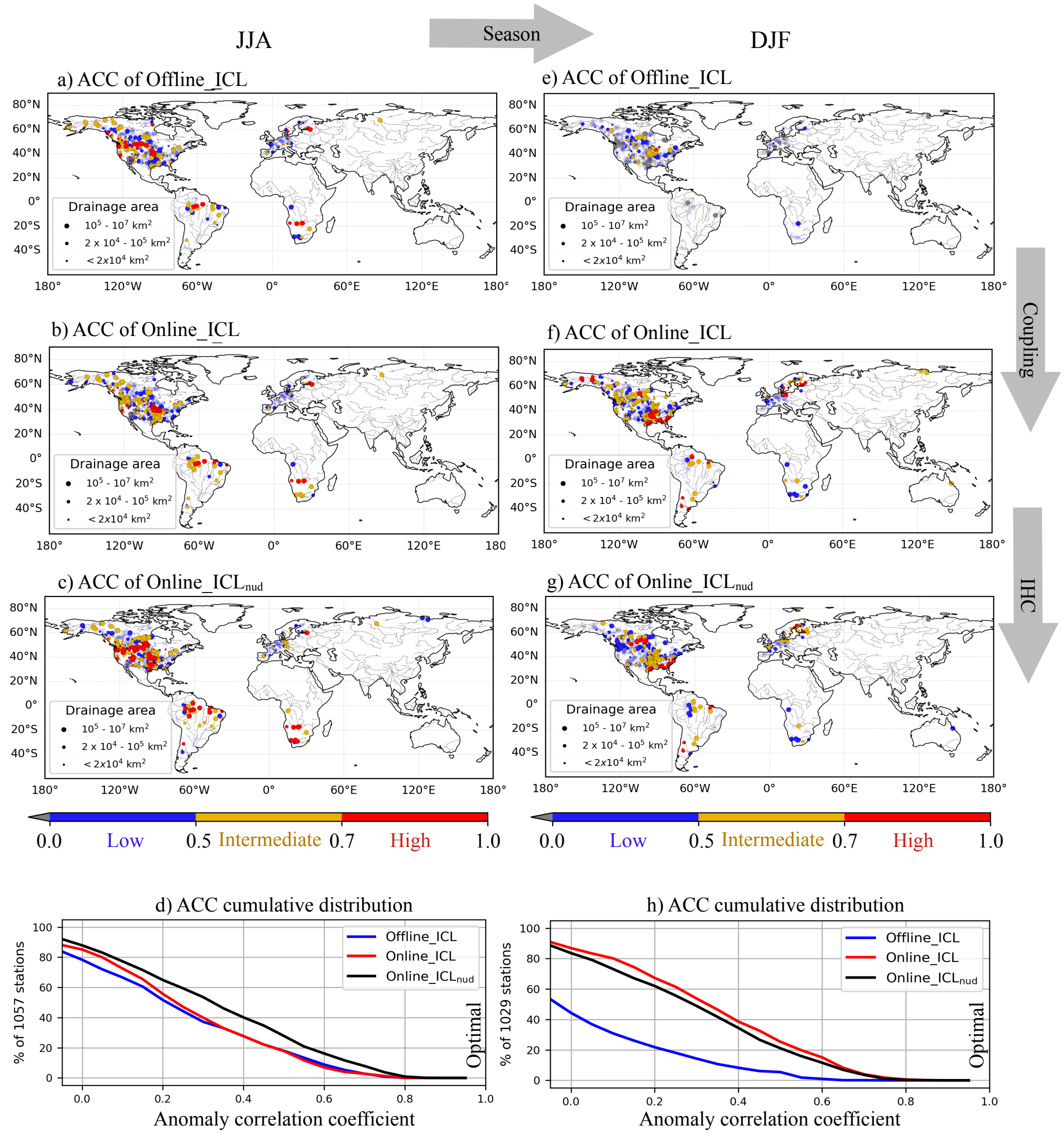


**Figure 7.** Anomaly correlation coefficients (ACCs) of bias-corrected streamflow hindcasts computed against observations in JJA (first column) and DJF (second column). Offline_ICL benchmark (First row) and the online coupled configurations with conventional initialisation (second row) and improved initialisation (third row). Cumulative distribution of the anomaly correlation coefficient of the corresponding season (last row). Markers with transparency represent stations with a statistically non-significant ACC at the 95% confidence level.

9. Figure 12: There are red curve lines overlapping with the legend text. This visualization issue will be corrected in the revised manuscript.

10. Line 300: "Arid regions" here, which specific areas are being referred to? This is not clear to me. It was

a typo. We referred to all of North America, not only the arid regions. The new corrected sentence in the manuscript is:

During summer, in North America ~~'s arid regions~~ (Figure 12a-b), the enhanced initialisation provides about 25% of additional skill (Figure 12c).

11. Line 313: The phrase "remains limited for most conrespecttinents" likely contains a typo. Please check or clarify. This typo has been corrected in the revised version of the manuscript. The right statement is: In JJA and DJF, the reduction of RMSE, if any, remains limited for most continents.~~conrespecttinents.~~

# References

Zomer, R. J., Xu, J., and Trabucco, A.: Version 3 of the global aridity index and potential evapotranspiration database, Scientific Data, 9, 409, https://doi.org/https://doi.org/10.1038/s41597-022-01493-1, 2022.