UK Hydrological Outlook using Historic Weather Analogues

Response to reviewers

Reviewer #1

Thank you for this well-written and timely manuscript, which describes a new experiment in the UK national hydrological forecasting system. The method incorporates historical observations from analogue months by matching the large-scale circulation patterns, and use them as forcings to generate hydrological forecasts. The study shows improvements in seasonal forecasts skills and event categorization, particularly in winter (the rainy season). This work is both important and valuable for the hydrological forecast community.

>> We thank the reviewer for their detailed comments on our manuscript. We are glad the reviewer recognises the importance of our results and the value of the methodology for the hydrological forecast community. Please find below our response in red.

Below are some comments to further discuss the idea with the authors and improve readability:

Line 68, Consider specifying “summer NAO (SNAO)" when first time refer to it.

>> Thanks – this will be changed in the revised manuscript.

Line 86, section 1.2, The section mentions four forecast categories, but the introduction states there are "three strands." Please clarify this. And the methods in the first category might be better to conclude as "descriptive forecasts" to distinguish them from ensemble-based approaches that come later.

>> Thank you for noticing our error. We will make clear in our revised manuscript the four strands. We will also adopt the reviewer’s suggestion and to distinguish between “deterministic forecasts” with “ensemble-based approaches”, also addressing reviewer 2’s suggestion of aligning this section with standard forecasting terminology.

Line 144, Are analogue months considered independently (i.e., monthly NAO indices)? Have you tested using moving-window averages for NAO to account for variability in selecting analogues?

>> Analogue months are considered independently. In the winter seasonal forecasts (i.e. DJF), the monthly NAO values are accounted for in the analogue selection procedure. However, when matching MSLP patterns, only the seasonal mean MSLP pattern I used for analogue selection based on spatial similarity of the forecast MSLP pattern. We will clarify this in the revised manuscript.

Line 220, Could you clarify why 17 ensemble members were chosen here? A flow chart illustrating the selection process would be helpful.

>> There are currently 17 hindcast members available for each of the three initialisation dates (i.e. giving 51 ensemble members per season). The resulting 51 ensemble members is broadly similar in size to the operational forecast so is considered a fair reflection of the operational forecast skill. We will more clearly point readers to Stringer et al., (2020) which provides the details of the hindcast ensemble and analogue selection methodology.

Line 235, For analogue season selection, have you plotted rainfall patterns for an example season to assess consistency among analogue months? It would be interesting to see such visualization (e.g., a map or time series).

>> Thank you for the suggestion. We would include a time series of the hindcast ensemble mean rainfall and observed mean rainfall for the different seasons in the revised manuscript.

We note that our companion paper (Rhodes-Smith et al., in review - https://doi.org/10.5194/egusphere-2025-2506) already includes a figure showing correlation of hindcast ensemble mean rainfall and observed rainfall across Great Britain (figure 2 in their paper).

Line 336, The text here continues analyzing results from Figure 3. But it reads like it is from Figure S1. Just specify it would help.

>> We will specify that we are writing about the results from Figure 3 here, and not Figure S1.

Line 341, What does "heterogeneity" refer to here, between the areas or between the methods? How are the numbers reflecting heterogeneity, could you explain a bit more.

>> Heterogeneity here just means large variation in CRPSS values within the different hydroclimate regions. We will rephrase to "there is substantial variation in CRPSS for catchments within each hydroclimate region".

Line 348, consider adding the catchment numbers together with the ratio, e.g. XX out of YY.

>> Thank you for the suggestion. We will add the number of catchments within each region in the revised manuscript.

Line 388, Typo: "--0.38" should likely be "-0.38." Is this value statistically significant? We will quote statistical significance in each sub-panel in the revised manuscript.

>> Thank you for spotting the typo, we will correct in the revised manuscript.

Line 420, Figure 7, This is an excellent visualization. I also noticed that for summer, both high flow events and low flow events had a drop in performance using HWA. Could this reflect challenges in low-flow forecasting? Since later in the discussion the authors mentioned summer is a future target, so maybe already mention it here while discussing the results for summer months.

>> Thank you for your comments on the figure visualisation. The reviewer is correct that summer flow predictability for summer months have dropped when using the HWA method, mainly outside of groundwater-dominated, slow-responding catchments in the south and east. We agree that this is an on-going challenge for low flow forecasting and will mention this particular challenge in the revised manuscript results section.

Line 452, Is it better to show the correct ratio for each station instead of the full distribution? Or if distributions are preferred, please just specify the reasons.

>> We have adopted to show the full distribution as this is the standard format for visualising forecast results from the UK Hydrological Outlook. The visualisation approach and the colours have been adopted after extensive stakeholder consultation and is operationalised via both the monthly Hydrological Outlook and in the interactive online Outlook portal (see https://ukho.ceh.ac.uk/). We will include this justification in the revised manuscript.

Line 499, In some sections, the authors attribute skills in some areas like the south and east to initial hydrological conditions or river memory. Is this based on prior knowledge of basin characteristics?

>> The skill in some areas, such as the south and east, are attributed to strong influence from initial hydrological conditions and catchment memory. As a result, the river flow predictability across these regions for both the standard ESP and HWA methods are high. This region contains mainly groundwater-dominated catchments with high catchment storage. This has been shown in the rigorous skill assessment of the standard ESP method in Harrigan et al., (2018) using the same set of catchments, including relating ESP skill to total catchment storage. Catchments in these regions also yield skilful persistence forecasts (i.e. persistence of flow anomaly from previous month), as shown by Svensson et al. (2016). We will strengthen this statement by referring to past work and knowledge of basin characteristics.

Some other thoughts:

Given HWA's success in winter, would you consider a dynamic framework switch between forecasting methods seasonally (e.g., HWA in winter, other methods in summer)?

>> This is an excellent suggestion. We are currently working on this topic. There is already some discussion of multi-model and multi-method forecast blending in the current discussion section, but we will further highlight the potential of improved performance and reliability of hydrological forecasts by blending forecast products based on forecast skill assessed over a hindcast period. We will also refer readers to Tanguy et al., (2024) which also proposed a similar idea for a "*flexible combinatory system that would dynamically choose the most effective method based on specific factors such as catchment characteristics, time of year and lead time*".

And for summer, are there other alternative indices that might outperform NAO for selecting analogues?

>> Thank you for this suggestion. We agree that a focus on alternative indices could potentially improve summer forecast skill. We have discussed this possibility in the original manuscript's discussion section: *"Improvements in the predictability of the East Atlantic pattern, which exhibits strong influence on rainfall variability, particularly across southern Britain (West et al., 2019), could contribute to further advances in national summer river flow predictability".* We will also make reference to potential improvements in summer flow predictability with better understanding of large-scale atmospheric teleconnections. Recently, Chevuturi et al., (2025) have demonstrated that the predictability of UK summer river flows and drought is linked to variations in North Atlantic sea surface temperatures and its atmospheric teleconnection pathway, which shows signs of predictability at a 1.5 years lag time. This improved understanding of teleconnections can be utilised to improve summer river flow predictability.

Just curious, what is the ratio of autumn/winter rainfall?

>> The ratio of UK average autumn/winter rainfall is 1.04

References:

Chevuturi, A., Oltmanns, M., Tanguy, M., Harvey, B., Svensson, C. and Hannaford, J., 2025. Oceanic drivers of UK summer droughts. *Communications Earth & Environment*, *6*(1), p.437.

Harrigan, S., Prudhomme, C., Parry, S., Smith, K. and Tanguy, M., 2018. Benchmarking ensemble streamflow prediction skill in the UK. *Hydrology and Earth System Sciences*, *22*(3), pp.2023-2039.

Svensson, C., 2016. Seasonal river flow forecasts for the United Kingdom using persistence and historical analogues. *Hydrological Sciences Journal*, *61*(1), pp.19-35.

Stringer, N., Knight, J. and Thornton, H., 2020. Improving meteorological seasonal forecasts for hydrological modelling in European winter. *Journal of Applied Meteorology and Climatology*, *59*(2), pp.317-332.

Tanguy, M., Eastman, M., Chevuturi, A., Magee, E., Cooper, E., Johnson, R.H., Facer-Childs, K. and Hannaford, J., 2025. Optimising Ensemble Streamflow Predictions With Bias Correction And Data Assimilation Techniques. *Hydrology and Earth System Sciences*, *29*, pp.1587-1614.