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Interactive comment on "Evaluating residual error approaches for post-processing monthly and seasonal streamflow forecasts" *by* Fitsum Woldemeskel et al.

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Response to Referee #1 General comment: This review is for Manuscript ID: hess-2018-214, entitled Evaluating Residual Error Approaches for Post-processing Monthly and Seasonal Streamflow Forecasts, authored by Fitsum Woldemeskel and coauthors. With this manuscript the authors' aim is to evaluate different residual error models, including logarithmic (Log), Log-Sinh, and Box-Cox transformation schemes, for post-processing monthly and seasonal streamflow forecasts. Overall, the postprocessed streamflow forecasts demonstrate skillful, reliable and sharper forecasts compared to the uncorrected forecasts. Furthermore, postprocessor employing the Box-Cox trans-

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Discussion paper

formation scheme demonstrate the sharpest forecasts, without sacrificing skill and reliability. This manuscript is generally clear, however, it reads like a book chapter rather than a journal article. I believe the results and conclusions are of interest to the HESS community, as well as to the operational forecasters. Thus, this manuscript is worthy of publication if the issues below are addressed.

Author response: We thank the reviewer for the positive assessment of our manuscript as well as for their constructive comments and useful suggestions to improve the manuscript further. We are pleased that the reviewer found our manuscript suitable for the HESS research community and the community of operational forecasters. We provide specific responses to review comments as follows.

Major Comments

Referee comment 1: The introduction needs better organization. Consider removing the unnecessary details about the statistical modelling system and hybrid system (P4-5, L86-95), which are irrelevant in the context of dynamic modeling. The literature review can be focused on the usefulness of POAMA-2 in advancing seasonal hydrological forecasting.

Author response: We agree that statistical and hybrid systems are not directly relevant in the context of dynamic modelling. In the revised version, we will ensure the description of statistical and hybrid approaches focus on the essentials and avoid excessive details. We will also elaborate on the usefulness of rainfall forecasts, including POAMA-2, for streamflow forecasting.

Referee comment 2: Make a separate subsection for the study area, dataset and hydrological model.

a) Study area: Provide general information on the hydroclimatic conditions, types of events across different seasons, basin size range, and reason for selecting the particular catchments.

Author response: Thank you for this suggestion. We will add separate subsection for study area with additional details about the catchments studied. As we are evaluating 300 catchments, it will be difficult to provide detailed site specific information, however, we intend to provide summarised information highlighting those points suggested by the reviewer.

b) Dataset: Provide detail information on rainfall forecast dataset from POAMA-2, including forecast lead time, total number of ensemble members, and forecast initialization time and frequency. POAMA-2 information (P7, L189-194) should be integrated into the "Section 3.1 Data".

Author response: We will add additional information about rainfall forecast using POAMA-2 as well as integrate the POAMA-2 information (p7, L189-194) into Section 3.1.

c) Hydrological model: I am concerned about the details of the rainfall-runoff model GR4J used for the study. It is necessary that you explain better the following aspects of the model: lumped conceptual model or physically based model, spatial resolution of the model, and the selected routing method. How often is the model initialized to make the forecast runs?

Author response: Thanks for raising this issue. In the revised manuscript we will include additional details about the GR4J model.

Referee comment 3: If the model is calibrated, then consider adding a subsection to discuss the simulation performance. You need to mention the calibrated parameters, model warm-up period, calibration period and validation period. The simulation performance can be discussed using correlation coefficient, percent bias and Nash-Sutcliffe efficiency between the observed and simulated streamflow.

Author response: Yes we have calibrated the GR4J model parameters. We use 5 years model warm-up during 1975-1979 as well as calibration and validation during

1980-2008 in a moving 5 years leave-out cross-validation scheme. We will make these points clearer in the revised manuscript.

In the paper, we have focused on forecast performance as this is the operational goal of the Bureau of Meteorology. In addition, we are using the same calibrated hydrological model for the three error modelling schemes, thus the results and conclusions regarding the error model schemes remain the same regardless of the simulation performance. Considering these and for conciseness, we will limit the analysis and results on forecast performance.

Referee comment 4: In order to support the operational forecasting system, the conclusions drawn here should be valid in the context of extreme events. Does the conclusions apply to flood events? For this, verification metrics can be computed by considering the flow amounts greater than that implied by a non-exceedance probability, in the sampled climatological probability distribution, of 0.95.

Author response: While seasonal streamflow forecasts have limited application for flood prediction purposes, the question is relevant for predicting drought events, where the seasonal forecasts have significant value. In this study we evaluated forecast performance separately for high and low flow months, which provides an indication of predictive ability for below-average flows (i. e., drought events). In addition, the results and conclusion regarding the best performing error model scheme and its performance apply for the extreme events.

Having said that, robust evaluation of forecasts at extreme events (e.g. drought events only) is challenging as these events are rare. Limited sample size makes it difficult to make conclusive statements. For instance, with a full record of 30 years used for calibration, if we want to test against <5% or >95% of historical data, we might have only roughly 1.5 samples to be tested for each month/season, which will add high uncertainty to the verification results and make it difficult to draw definitive conclusions. To handle this uncertainty requires the development of new forecast verification techniques potentially adapting some of the approaches for groups of catchments used by Hodgkins et al. (2017). As the development of new forecast verification techniques is outside the scope of this current study, we will include a paragraph in the discussion to acknowledge this issue and recommend it for future investigations.

Referee comment 5: Considering an operational forecasting situation, how feasible is it to run 166 ensemble members using 40 GR4J parameters, and produce 6640 daily streamflow forecasts?

Author response: Yes, it is feasible to run 166 ensemble members with 40 GR4J parameters, and the Bureau of Meteorology has been running such a system operationally for a few years now. Producing 6640 forecasts this way is important to maintain reliability of forecasts. The largest computational expense results from calibrating hydrological models and cross-validation exercise rather than updating streamflow forecasts once every month using 166 ensembles members. However, the calibration and cross-validation exercise is typically done using a single observed rainfall time-series. We also use high performance computing (HPC) facilities available at the Bureau of Meteorology and the National Computing Infrastructure (NCI) for calibrating hydrological models, which significantly reduces overall computation time. We will mention this in the revised manuscript.

Referee comment 6: In the context of seasonal forecasting, different studies have demonstrated the combined ability of preprocessing meteorological forcing and post-processing streamflow forecast to produce better streamflow forecasts. However, the study here only implements postprocessing. Was the meteorological forcing preprocessed? If not the case, it could be a topic of discussion, as a recommendation for future work to investigate the performance of residual error models in the context of preprocessing and postprocessing.

Author response: We use the analogue approach to downscale gridded POAMA-2 rainfall forecast to catchment scale forecast, which can be considered as some form of pre-processing. We will highlight this point in the revised manuscript.

Minor Comments

Referee comment 7: Figure 8: Mention the units in the Y-axis for streamflow.

Author response: Thank you for this suggestion. We will include units in the Y-axis in Figure 8.

Referee comment 8: Figure 8: Is there any reason for selecting Dieckmans Bridge catchment as a representative site for the analysis. Why is the time series plotted only for the period of 2003-2007? Is this a random selection?

Author response: Dickmans Bridge catchment is selected as it is reflective of the results and conclusions across all catchments. That is, applying BC0.2 at this catchment resulted in better sharpness compared to applying Log and LogSinh while maintaining comparable CRPSS and reliability for high and low flow months. This is shown in Figure 9. The period 2003-2007 in Figure 8 is chosen as this period shows the difference in the forecast interval between the raw and three error models more clearly. We will highlight this point in the revised manuscript.

Referee comment 9: Figure 9a: Replace "CRPS" with "CRPSS" in the Y-axis. Referee comment 10: P8 L200-204: Integrate this paragraph into the introduction. Referee comment 11: P9 L233: Provide a reference to the statement: "the parameters are estimated based on the methods of moments." Referee comment 12: P13 L365: Define the variable "y" in Equation 11. Referee comment 13: P13 L367: How do you define the Heaviside step function? Referee comment 14: P16 L444: Fix the typo for "Figure 45i". Referee comment 15: P18 L495: Replace "unprocessed" with" uncorrected". Referee comment 16: P18 L501: Define the acronyms: "NSW", "QLD" and "NT" when used for the first time.

Author response: We thank the reviewer for pointing out the above editorial corrections (comments 9-16). We will incorporate these corrections in the revised manuscript.

Referee comment 17: It may be good idea to provide a standard name for the streamflow postprocessing technique implemented in the study, is it a new technique? If not, then provide a suitable reference to the postprocessing technique.

Author response: We thank the reviewer for this suggestion. The residual error model approach used in this study is not new (e.g. the Box-Cox / power transformation has been introduced by Box and Cox, 1964; see McInerney et al., 2017 for detailed analysis), however, the application of it for post-processing monthly and seasonal streamflow forecasting in national forecasting system is new. We will clarify this in the revised manuscript.

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