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Hydrology and Earth System Sciences
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Discussions

Interactive comment on "Statistical forecast of seasonal discharge in Central Asia for water resources management: development of a generic linear modelling tool for operational use" *by* Heiko Apel et al.

Anonymous Referee #1

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There is an urgent need to improve the safety and operation of impoundments in Central Asia, yet hydrometeorological data to support inflow forecasting and water management are in short supply. This manuscript seeks to address these needs by developing a standard multiple linear regression model of melt season (April-September) discharge in 13 catchments. Forecasts are based on suites of predictors (precipitation, temperature, snow cover and composite variables) in January to June, and tested using a cross-validation technique applied to 16 years of monthly data. Following an exhaustive evaluation of all possible permutations of monthly and averaged predictors,

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Discussion paper

best-performing models, and 20 near-optimal models are retained. The attendant mix of predictors and uncertainty bounds are then examined for months leading up to and at the start of the forecast season. Variations in forecast skill are qualitatively linked to catchment characteristics.

The overall approach to model development is necessarily pragmatic given the data and technical constraints of the region. Despite the simplicity of the approach, high explained variance (R2) is reported and the authors have bounded forecasts using envelopes of predictor suite uncertainty. However, it is unclear whether the underpinning data comply with the assumptions of the MLR model (i.e. linearity of relationships, homoscedasticity, no outliers, normally distributed and uncorrelated residuals). Furthermore, given the small number of cases (16) and relatively large number of independent variables (4) it is essential that significance levels and adjusted R2 values are reported for all retained MLR models. Significance of the model coefficients should also be tested and any insignificant variables removed. In some models, the predictor variable (e.g. May discharge) is not fully independent of the forecast variable (April to September discharge).

On this basis, publication is recommended subject to the following major revisions, minor corrections and clarifications.

Main comments

[Abstract] Please incorporate more headline results, such as the range of forecast skill for forecasts issued before the onset of the main melt season, as well as typical forecast biases.

[Table 1] Add additional information on the mean annual precipitation, temperature and winter snow cover area in each catchment.

[Section 2.1] Explain the method and purpose of the hierarchical clustering. What metrics were used to compare catchments and to establish cluster membership? The three clusters should be linked much more explicitly to subsequent discussions of predictor sets (in section 4.2).

[Section 3] How significant are evaporative losses from the catchments and how might this component of the water balance be represented within MLR models?

[Section 3.1] To maintain independence of the predictors, only variables up to March should be used to build models of April-September discharge. After March, the forecast period should be progressively reduced. For instance, predictors between January and April could be used to build models of May-September discharge, January to May variables for June-September discharge, and so forth. Results from models with overlapping predictors and forecast variable should be removed.

[Section 3.2] More rigour is needed in testing for violations of MLR assumptions (i.e. linearity of relationships, homoscedasticity, no outliers, normally distributed and uncorrelated residuals). This could be captured in tabular format with a matrix showing which assumptions (if any) are violated in each catchment.

[Section 3.3] Equations for the lmg algorithm should be provided, and the method of selecting predictors should be described more clearly. Significance of all model coefficients should be formally tested and any insignificant variables removed. All reported R2 values should be adjusted for sample size, and accompanied by a statement of significance. Then, only models that pass the specified level(s) of significance should be retained.

[Table 2] Report only adjusted R2 values for the overall best, and 20 best models. Results for forecasts issued in April, May and June should only cover the periods May-September, June-September and July-September respectively. The legend should be updated accordingly.

[Section 4.1] The discussion of predictive uncertainty should acknowledge other components, including from data quality, choice of model type/ structure, choice of objective function(s), model parameters. As noted, the uncertainty bands associated with the 20 best models reflect the number of models retained. When more stringent tests of model skill are applied (see comments on section 3.3 above), fewer models may pass. In any event, the criteria for model inclusion within the ensemble used for uncertainty estimation should be stated explicitly.

[Section 4.3] Add a paragraph on the specific operational decisions that are already, or could be, supported by seasonal discharge forecasts in Central Asia.

[Conclusions] Note that seasonal forecasting of precipitation could provide useful information in catchments and years with relatively little winter snowpack accumulation. Seasonal and sub-seasonal forecasts of extreme rainfall could also be important for hazard management (floods, landslides) and dam safety. Note also that the winter precipitation, summer melt situation applies in the Western U.S. too. Add a paragraph on further research opportunities.

Minor corrections and clarifications

[P1, L19] Note that seasonal forecasts can also contribute to improved dam safety.

[P1, L31] State the range of river catchment areas.

[P2, L7] Typo "The Central Asian region. . ."

[P2, L25] Omit "actually".

[P3, L4] Provide full publication details for the Hydromet Services questionnaire.

[P4, L27] Typo "catchmentss".

[P4, L27] Note that some of the catchments are nested (i.e. not independent) such as the Upper Naryn and Naryn, so the actual sample size is smaller than 13.

[P7, L12] Non sequitur – please clarify why the need for cross-validation and hierarchical clustering follows from the observation that the discharge regimes vary between catchments.

[P10, L20] Presumably all variables used in composites (e.g. temperature and precipitation) are normalized by their mean and variance such that they have equal weight in the MLR model?

[P11, L4] Provide the equation for the Predicted Residual Error Sum of Squares (PRESS). Note also that had a different objective function been selected, different sets of predictors might have emerged.

[P11, L14] Please clarify "a set of specific models of the best models".

[Figure 4] Improve legibility by removing the grey background from each panel. Avoid use of red with green lines as these will be indistinguishable for some readers.

[Table 3] Explain how the number of "good" forecasts can be higher for the mean than for the best model in some catchments (e.g. Uba, January).

[P19, L22] Please clarify "possible lack of representativeness of the time series used for the "real" variability of the seasonal discharge in Central Asia".

[P21, L7] Please clarify the sentence "This indicates that the predictor selection. . ."

[Figure 7] Ideally the presentation and discussion of the predictors would be organized by the three clusters described in section 2.1.

[P24, L3] Typo "precipiutation".

[P24, L25] Report only adjusted R2 values with accompanying significance level(s).

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