Response to Reviewer #1

Dear Reviewer, we are grateful for your thoughtful comments and suggestions. Following is our reply to the points raised in your feedback; and it is structured as comment from reviewer (bold text) followed by our response to the comment. Where relevant, the specific changes are also highlighted.

Review of "Parameter uncertainty analysis for an operational hydrological model using residual based and limits of acceptability approaches"
The manuscript is well-written and in line with the scope of this journal. It targets three different objectives: (1) uncertainty quantification / parameter estimation applied to an operation hydrological model; (2) investigation of the impact of using additional data to the output of the parameter estimation procedure; (3) assessment of using a timerelaxed (instead of limits-relaxed) GLUE LOA approach. The approach is technically sound. Many aspects are addressed in a practical way, based on best-practices or heuristic approaches, leaving room for future more theoretically-oriented investigations. The approach here is fairly justified by the objective of applying the methodology to a real-case scenario.
The conclusions are supported by an adequate number of tables and figures. As highlighted in one comment below, I think that the authors should provide more insights related to the interpretation of these results.
For these reasons, I would recommend to accept it with minor revision.

As presented in our response to the following specific comments; additional references, explanations and figures have been provided in order to improve the manuscript through better readability and through the provision of additional insights into the work presented in the manuscript.

1 - Introduction: page 1, line 23: add reference or short inline explanation about the context for those readers who are not familiar with this company

A citation within the text has been added as follows:

Statkraft (2018) has recently released a new modelling framework mainly tailored for an operational purpose.

The following full reference has been added in the list of references section:
Statkraft information page: https://www.statkraft.com/, last access: 20 June 2018

2.1 - The hydrological model page 5, line 3: please add more information about the rationale behind the choice of these seven parameters and the corresponding low/high bounds.

Additional information has been provided as follows

In the default parameter settings of the PT_GS_K model seven parameters are considered as influential and thus allowed to vary in conditioning the model. Preliminary model calibration using the BOBYQA algorithm (Powell, 2009) and the default setting gave reasonable model performance. Hence, the same setting was also followed in this study with the addition that the sub-grid snow coefficient of variation was also considered an uncertain model parameter. A similar result was also observed when this setting was latter verified using the method of Morris (Morris, 1991; Saltelli et al., 2008) for screening the most influential out of the relevant model parameters.

The following information has been added in section 2.3.1 regarding the low/high bounds of the selected model parameters, The feasible ranges of parameter values are set based on relevant literature and previous modelling studies in the Nea-Nidelva catchment.

2.2 - Study area and data I would suggest to add a figure depicting a map of the study area

The following physiographic and location map of the study area (Figure 1) has been added in the 'Study area and data' section. The figure number of the other figures and references to the figures in the manuscript has been updated accordingly.

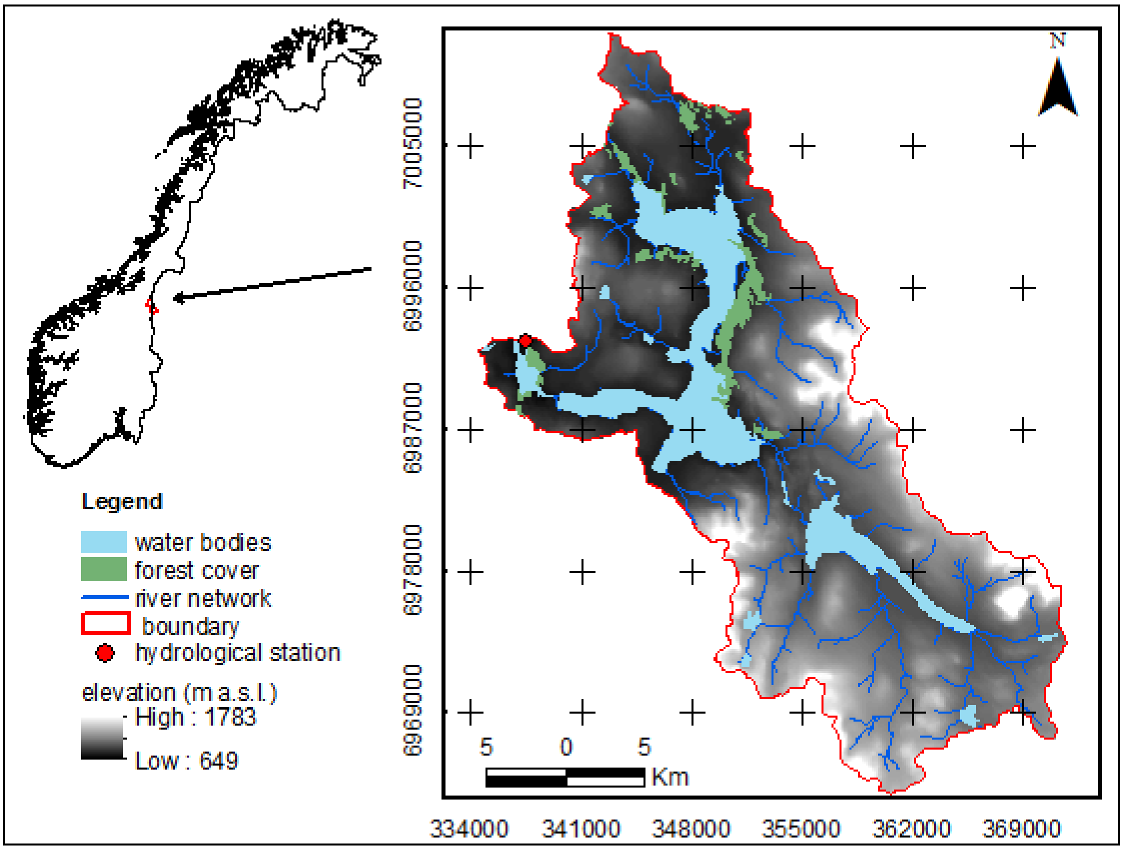

Figure 1. Physiographic and location map of the Nea-catchment in Norway

3 - Results Figure 4 is not well readable in my opinion, because the variables are misaligned. An option could be to build a grid of subplots, leaving axis labels outside the grid and reporting the scatter plots of interest on the upper-diagonal cells and, for example, correlation values on the lower-diagonal. I leave the final decision to the authors.

Sub-plot labels are now placed in the diagonal cells, the scatter plots above the diagonals and the new cells with correlation coefficient scores have been added below the diagonals. A reference to the correlation coefficient scores is also included in page 9, line 32 as follows.
The aforementioned less sensitive model parameters can, however, have high effect on model outputs through interaction with other parameters. Some degree of interaction between model parameters can be seen from the correlation shown in Fig. 4. For example, a general decreasing trend in model performance can be noticed with a joint increase in *c1* and *c2*. The strong influence of *tx* in constraining the output is also evident in these plots. A considerable level of interaction can also be observed from the correlation coefficient scores between *c1* and *c2* (0.56), *c2* and *c3* (0.53) as well as between *tx* and *wind scale* (0.66).

Figure 4 and its caption have been modified as shown below:

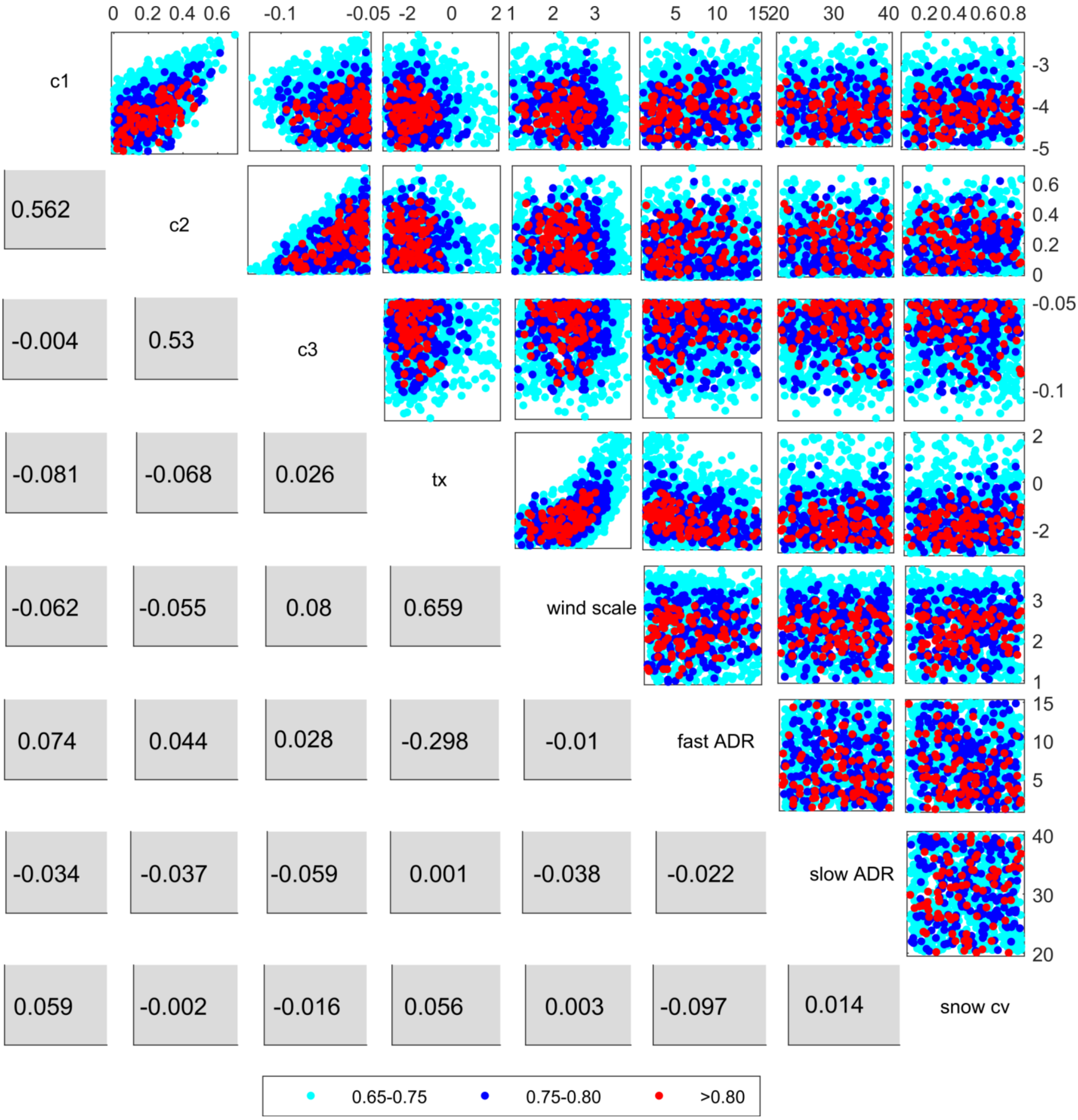

Figure 4. Model performance in response to the interaction between model parameters (upper diagonal cells) and correlation coefficient scores between the parameters (lower diagonal cells)

Page 10, line 13: why the validation results pertaining to year 2014 was not included in the corresponding figure 6? Please also elaborate on what are the possible motivations behind the poor performance of the behavioral models evaluated using LnNSE in year 2014.

Plots depicting the validation result of using observations from year 2014, both when model parameters are identified using NSE alone (Fig. 6c) and when using combined likelihood (Fig. 6d), have been included in Figure 6. The following explanation was also added in page 10, line 14, regarding the possible reasons for the observed poor performance when behavioural models are evaluated using LnNSE in year 2014:

This can be attributed to the relatively low quality of streamflow observations during the low streamflow period of this year. The validation result was also highly affected by nature of the likelihood measure used during the identification of behavioural models. For example, a persistent low performance was observed during early months of the hydrologic year when validating model parameters identified using NSE alone (Fig. 6c) as compared to those identified using the combined likelihood (Fig. 6d). Similarly, excluding the first 30 observations from the validation dataset resulted to an improvement of LnNSE from -0.53 to 0.44.

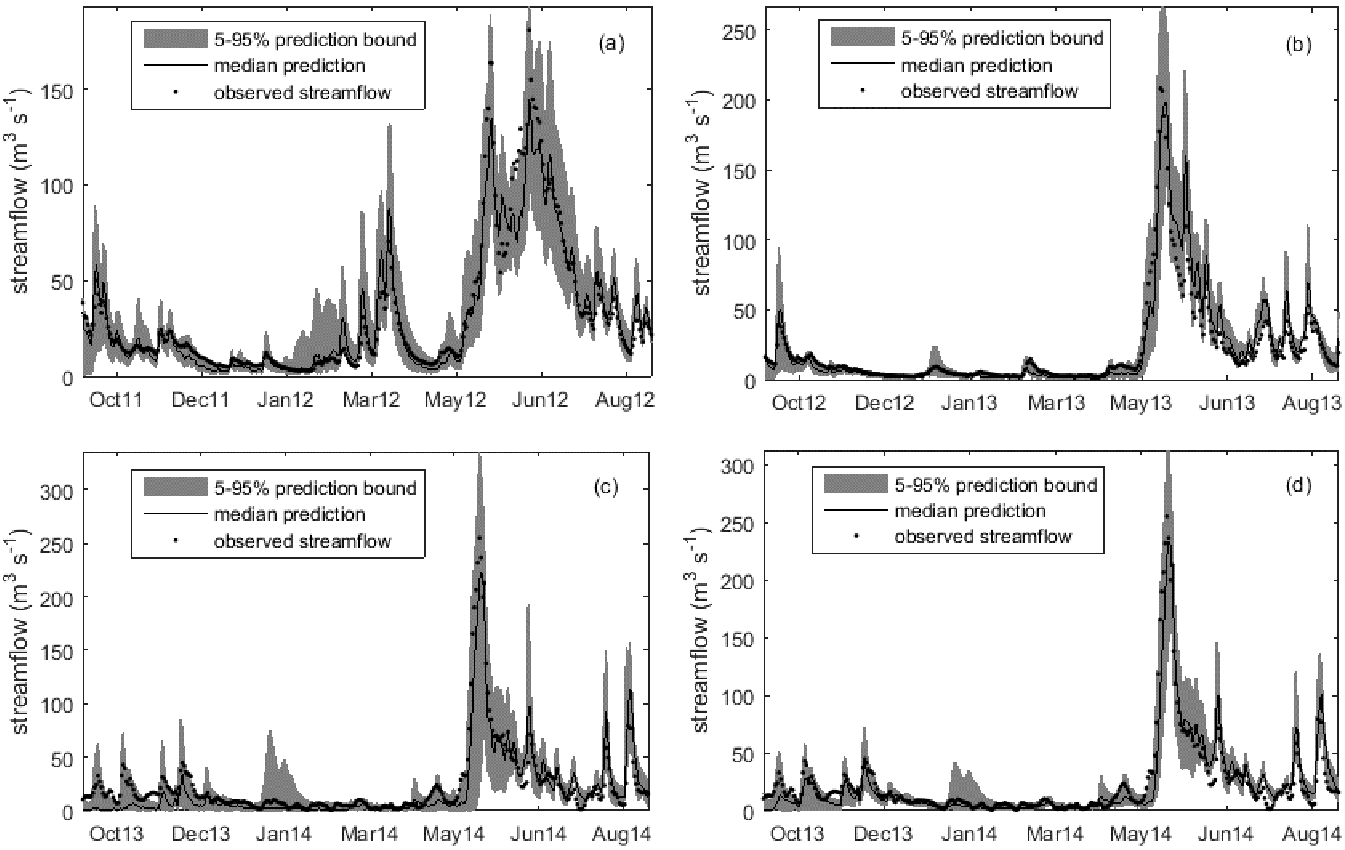

Figure 6. Median, 5-95 percentile range and observed values of streamflow for sample calibration period (a) and validation periods (b, c and d). The calibration result (a) as well as the validation results presented in (b) and (d) are based on behavioural models identified using the combined likelihood, while the result shown in (c) is based on behavioural models identified using NSE alone.

New references:

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Morris, M. D.: Factorial sampling plans for preliminary computational experiments, Technometrics, 33, 161-174, 1991.
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Saltelli, A., Ratto, M., Andres, T., Campolongo, F., Cariboni, J., Gatelli, D., Saisana, M., and Tarantola, S.: Global sensitivity analysis: the primer, John Wiley & Sons, 2008.
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Stedinger, J. R., Vogel, R. M., Lee, S. U., and Batchelder, R.: Appraisal of the generalized likelihood uncertainty estimation (GLUE) method, Water resources research, 44, 2008.
Wagener, T., McIntyre, N., Lees, M., Wheater, H., and Gupta, H.: Towards reduced uncertainty in conceptual rainfall-runoff modelling: Dynamic identifiability analysis, Hydrological Processes, 17, 455-476, 2003.