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Hydrology and Earth System Sciences Discussions

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Interactive Comment

Interactive comment on "Comparison of different multi-objective calibration criteria of a conceptual rainfall-runoff model of flood events" *by* N. Chahinian and R. Moussa

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We would like to thank the three reviewers for their interest in our work and their constructive comments regarding this manuscript. All their suggestions are being taken into account for the revised version of the paper.

1. Common queries made by all three reviewers

All three reviewers require a clear presentation of the calibration procedure:

1.1. The calibration procedure and the a priori ranges of model parameters (Reviewer 1, point 1; Reviewer 3, points 3 and 4)

A coupled manual and automatic calibration procedure was used. In the first phase the manual procedure, based on the results of previous sensitivity analysis on field data, and on a "trial and error calibration" approach, is used. It enables to obtain a set of parameters to simulate each flood event separately (Moussa,1991; Moussa et al., 2007) and then proceed to a collective calibration of flood events (Chahinian et al., 2005). Through this first phase the lower and higher limits of each parameter range are obtained. The second phase consists in an automatic calibration procedure based on model simulations using a progressively finer grid in space. The second phase aims at exploring the whole space of parameters, especially around the optimum obtained in the first phase. The initial grid is obtained by subdividing the interval of variation of each parameter into steps, not necessarily regular, on the basis of the results of the first phase. Then, around the points of the grid presenting local minima of the objective functions, smaller grid steps are defined. The procedure is repeated iteratively and guides the grid adaptation to focus on more promising regions in the space of parameters. In the applications, this procedure was first used for single-objective calibration runs. For the multi-objective procedure, the Pareto criterion was calculated using the results of the previous single-objective calibration.

1.2. The balanced aggregate optimum (Reviewer 1, point 2; Reviewer 3, point 1)

The method used herein calculates the Pareto optimum on the basis of all simulation results (page 1026, 1-15). A weighted single objective optimisation is done, that's why a transformation was used to compensate for different scales and units in the objective functions. We agree with Reviewer 3 that the nonlinearities and thresholds could yield non convex Pareto fronts (i.e. Fig 5a and 5c) and consequently could affect the use of the weighting schemes. In the revised version of the paper we will discuss this point and the generalisation of the approach to high numbers of objective functions, on the basis of international literature and the results of the study case.

2. Points raised by reviewers

2.1. Reviewer 1

Point 1: The calibration procedure (see above 1.1).

Point 2: The balanced aggregate optimum (see above 1.2).

Point 3: The problem of equifinality :We agree with the reviewer's remark to distinguish between the equifinality defined by Beven and Binley (1992) which is related to model performance measured with respect to likelihood measure, and the multi-objective equivalence of parameter sets defined in the terms of the Pareto criterion which is related to trade-offs between different objectives (Madsen, 2000).

Point 4: The shape parameter "z" : Generally, the shape parameter z ranges between 0.5 and 50 (Moussa and Bocquillon,1996). When "z" tends to the higher values (i.e. $z > 40$), the diffusive wave model tends to the kinematic wave model which calculates the hydrograph at the outlet as a simple translation in time of the input hydrograph. If the time step of calculation is large in comparison to the lag time parameter "w", the transfer model will give similar results for all high values of "z"; consequently for high values of "z", the hydrological model is not sensitive to "z". Herein, we used a small interval of z for lower values of "z" ($z < 1$) and a larger interval for higher values $z>1$. This procedure is equivalent to a Log transformation of parameter "z" which allows a better distinction between small and very large values.

Point 5: RMSE and Nash criterion : We agree with the reviewer that the Nash-Sutcliffe criterion and the RMSE are linked to each other.

Point 6: Use of the balanced objective function to more than two objective functions : Madsen et al.'s work (2002) on the use of four objective functions will be more thoroughly addressed.

Point 7: Rainfall spatial heterogeneity: As stated in the manuscript, rainfall is highly heterogeneous over this catchment and increases with elevation. It is true that a mean value of rainfall cannot fully express this heterogeneity. However, in lumped hydrologic models, one cannot distribute rainfall without altering the model structure into a

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semi-distributed scheme. Herein the number of rain gauge is seven, and the mean precipitation can be calculated using either simple graphical methods or more elaborate techniques based on spline functions or kriging methods. However Lebel et al.(1987) showed that on this catchment, for a small number of rainfall gauges (i.e. seven), the arithmetic mean and the Thiessen method yield comparable results to more complex approaches (kriging and spline functions). This will be mentioned in the new version of the manuscript.

Point 8: We agree that the differences between the values of the objective functions when using multiple and single objective calibration are a consequence of trade-offs.

Point 9: The volume based objective function is calculated in volume per time step. Consequently the corresponding objective function (i.e. less than 0.0001 m3/time step in Figure 4) is small in comparison to other objective function (i.e. the relative volume error ranges between 0.05 and 0.25 in Figure 5).

Point 10: The bold line in Figure 8 shows the measured hydrograph and the dotted lines show the various model simulations using the set of parameters from the multi-objective Vr-RMSEr-Pr procedure.

Point 11: In the revised version, the objective functions will be presented in the same order as in the text and in the equations.

2.2. Reviewer 2 (J. Parajka)

Point 1: The calibration procedure (see above 1.1).

Point 2: Initial conditions and their impacts on final event based model simulations: This issue will be fully discussed in the new version of the manuscript. As pointed out by reviewer 3, initial conditions can considerably influence modelling results. However, our model is more sensitive to the ratio between the initial and maximum storage capacities than to the value of the initial condition. The 5day antecedent rainfall index is frequently used in hydrological modelling (Brocca et al., 2007; Peugeot et al., 2003; Heggen,

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2001, Fedora and Beschta, 1989), although some studies have used wider time spans to calculate this index (Anctil et al., 2004), the 5 day rainfall is considered as a standard.

Point 3: Presentation of results : We agree with the reviewer's suggestion to add and discuss a figure which studies the impact of the selected objective functions on the hydrograph shapes.

2.3. Reviewer 3

Point 1: The balanced aggregate optimum (see above 1.2).

Points 2 and 3: The calibration procedure and the a priori ranges of model parameters (see above 1.1).

Point 4: Volumetric view of the three-objective calibration: For the three-objective calibration space, 3D plots (with projections on the three two-objective planes) will be added to the revised manuscript and fully discussed as it is done for the two-objective cases. We agree with Reviewer 3 that the paper presents an analysis in a 6-objective space, and that a single analysis using all single objective functions implicitly yields all the presented results. The reviewer's suggestion to present results moving from higher to lower dimensional analysis (i.e. from 6-, to 3-, 2- and single-objective functions) is interesting. However, it is not simple to analyse data in a 6-D space and even in 3-D space due to the functions' complex shape. Consequently, starting the analysis with single-, than 2- and finally 3- objective functions enables to analyse separately the shape of each objective function and then to cross the objective function 2by2, then 3by3, etc.

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