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Hydrology and Earth System Sciences Discussions
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Interactive comment on "Application of a model-based rainfall-runoff database as efficient tool for flood risk management" *by* L. Brocca et al.

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Referee 2 (P. Willems) (blue: Referee comments, black: author replies)

The paper presents a very interesting approach in support of operational flood forecasting. It does not follow the traditional approach of real-time simulation of forecasted rainfall in a hydrological model. It is based on a database in which the results from a huge number of model simulations are stored after post processing and classification. (Flood) events are in the database classified based on the forecasted rainfall, initial catchment wetness index and initial river discharge (after k-means cluster analysis). The real-time operational forecasts then follow some type of "analogue" method where forecasts do not need new model simulations but are based on the simulation result

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available in the database, for the specific class to which the forecast belongs.

The paper is well written and presents an interesting new approach. Therefore, I recommend publication in HESS, after the authors have addressed the reviewers' comments.

We thank the reviewer for his appreciation on our study.

Abstract: It does not become clear from the abstract how the approach works. After reading the abstract, I did not understood yet that the database stores pre-simulated events and that the flood forecasting system does not require new model simulations to be conducted. This only became clear to me after reading section 2. Therefore, I recommend that the authors rewrite part of the abstract to make the general approach more clear from the abstract alone.

We will revise the abstract to clarify how the approach works. Specifically, it will read (from line 9 at page 2090): "The rainfall-runoff model was used to simulate runoff on the basis of a large number of rainfall events. The resulting rainfall-runoff database stores pre-simulated events classified based on the rainfall amount, initial wetness conditions and initial discharge. Therefore, it can be used as an effective tool to assess possible streamflow situations assuming different rainfall volumes for the following days.".

Rainfall generation: Can the authors explain why a time step of half an hour was selected (this depends on the concentration time of the quickest runoff component of the catchment) and why five days was selected as duration for the rainfall events (also that depends on the catchment characteristics)?

The selected time step is related to the temporal resolution of rainfall and temperature observations. In the study area, the catchment hydrologic response could be very quick, mainly due to high rainfall intensities that sometimes occur at point scale. Therefore, we considered the finest temporal resolution that is available.

The duration of the rainfall events was selected to be sure to encompass the whole storm (i.e., without a truncation). These specifications will be added in the revised manuscript. Moreover, the number of days is just an example and due to the flexible structure of the framework, it can be easily adapted to the users' requirements.

Can the authors add to the paper their motivation for using a stochastic rainfall generator instead of historical series? The main motivation is of course the limited time span covered by historical series. The rainfall generator allows to simulate extreme events, but question is how reliable this extrapolation is? Figure 2 shows slight underestimations of the hourly rainfall extremes and overestimations of the 6-hour and 12-hour rainfall extremes (the latter is not mentioned in the text). I am not sure they can say that the NSRP model represents "reliably" the extreme values!? (see page 2098 - line 23)

The question about the reliability of the extrapolation of rainfall (and discharge, see below) extremes is really appropriate. In this paper, we used a stochastic rainfall generator to make our best to reproduce the statistics and extreme values of the observed time series. Generally, we believe that the performance of the Neymann-Scott Rectangular Pulse (NSRP) model is satisfactory, even though some under- and over-estimation might occur. These results are also in accordance with previous studies carried in the same area, but using different catchments (*Giustarini et al., 2010; Camici et al., 2011; Tarpanelli et al., 2012*). Therefore, we believe that the NSRP results in the study area are quite robust. However, we will smooth the sentence related to the NSRP model performance in the revised manuscript. Moreover, we appreciate the reviewer's comment as including historical rainfall events in the database is a good suggestion that can be effectively adopted to improve the database performance. This will be tested in future applications.

The authors checked the accuracy of the generation of the rainfall extremes in Figure 2, but did they also test the accuracy of the rainfall-runoff model in making extrapolations to extreme conditions? Approaches to test such performance have recently been proposed by:

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Vaze, J., Post, D.A., Chiew, F.H.S., Perraud, J.M., Viney, N.R., Teng, J. (2010), 'Climate nonstationarity – Validity of calibrated rainfall-runoff models for use in climatic change studies', Journal of Hydrology, 394(3-4), 447-457

Van Steenbergen, N., Willems, P. (2012), 'Method for testing the accuracy of rainfall-runoff models in predicting peak flow changes due to rainfall changes, in a climate changing context', Journal of Hydrology, 414-415, 425-434

Coron, L., Andréassian, V., Perrin, C., Lerat, J., Vaxe, J., Bourqui, M., Hendrickx (2012), 'Crash testing hydrological models in contrasted climate conditions: An experiment on 216 Australian catchments', Water Resources Research, 48, W05552

The authors should at least discuss the need to test the performance of the model to reliably simulate extreme conditions, because their results will be used for flood forecasting, whereas the model calibration was based on historical series in which only three flood events occurred. The NSE provides a test on the overall performance, but does not focus on the extremes. The model results are shown for the four largest events in Figure 4, but it would be useful to test as well the tail of the flow extreme value distributions.

These are two very interesting comments raised by the reviewer. We carefully read the references suggested by the reviewer (and we will add in the paper) and we fully agree about the possible limitations of rainfall-runoff models to predict discharge (mainly extremes) under changing climatic conditions. To partly address the reviewer's comment, we will analyse the capability of the procedure, i.e., the continuous simulation approach, to predict the frequency of maximum annual discharge (flood frequency) in the two catchments. A similar analysis was carried out by *Camici et al., 2011* in the same study area, but for different catchments, obtaining quite good results.

Moreover, we underline that in the paper we used the ANSE performance score just to put more emphasis in the calibration of the model parameters for simulating high flow conditions.

However, we are aware about the issue in making extrapolation of discharge (and rainfall) through modelling approaches and this issue will be highlighted in the revised manuscript.

Was the correlation between rainfall and temperature accounted for in the stochastic temperature generation?

The correlation between rainfall and temperature is not taken into account as we found a non-significant correlation between the two variables in the observed data. This will be specified in the revised manuscript.

How important was it to include the initial discharge? I assume that the antecedent wetness state is far more important as initial condition than the initial discharge (which may strongly depend on the wetness state). Did the authors check this?

The reviewer is fully right; the hydrologic response of the catchments in the investigated area is strongly dependent on the initial wetness conditions (e.g. *Brocca et al., 2009; 2010*). We have included initial discharge having in mind the operational use of the rainfall-runoff database. In an operational context, the initial discharge is known and this can be used as initial value of the forecasted discharge hydrographs extracted by the database and dependent on the forecasted rainfall for the following days.

How was the initial time step selected, in a consistent way in both the historical and generated events?

The initial time step was selected in a consistent way for historical and generated events by considering the time when the rainfall starts. However, we note that the forecasts obtained through the database have to be treated as synthetic predictions. Therefore, the temporal discrepancies between the observed and simulated discharge shown in Figure 5 are related to the synthetic nature of the simulations.

Page 2095 - Lines 15-16: The authors refer to their previous papers for the baseflow model, but can they add in a few words what “simple” method they applied. Linear

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reservoir model or a more advanced approach?

A non linear power function between the soil moisture storage of the model and the baseflow is considered. This will be specified in the revised manuscript.

I was surprised to read on page 2103 line 10 that one of the advantages of the approach presented by the authors is that it does not require hydrological modelling skills. I understand what the authors mean, but I suggest rephrasing this. Also in a traditional flood forecasting system, where the rainfall-runoff model has been prior calibrated, the system can be applied by operational users without good hydrological modelling skills (although such skills would be beneficial, not only for the developers of the system but also for the users ...). I do not see the difference (in terms of modelling skills required) between prior FFS development activities where a rainfall-runoff is calibrated and set for operational use, versus the prior development of the RR-DB proposal by the authors.

Actually, the rainfall-runoff database can be used by persons with limited skills in hydrological modelling. Indeed, the difference of our rainfall-runoff database to "traditional flood forecasting systems, where the rainfall-runoff model has been prior calibrated" is that is a well-founded database query (as described), where no model is involved anymore. The potential user might be an employee of an agency for flood risk management and water management which know of course their region and the related hydro-meteorological regime – which is basis for performing the query. But they do not need to have specific or advanced skills or experiences in hydrological modelling.

In their future research prospects, the authors may consider applying a data assimilation method for real-time bias correction.

Actually, we are already working on data assimilation, mainly in situ and satellite soil moisture assimilation into rainfall-runoff modelling (*Brocca et al., 2010 HESS; 2012 IEEE TGRS*).

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Abstract – line 14: “real flood events were appropriately captured by the database within an uncertainty range.” This is quite trivial; model results are always captured within an uncertainty range ...

We will remove the part: "within an uncertainty range".

Page 2091 – line 24: change “FFSs” to “FFS”

Title of section 2.4.1: typing error in “Precondition”

These two corrections will be made in the revised manuscript.

Additional References

Tarpanelli, A., Franchini, M., Camici, S., Brocca, L., Melone, F., Moramarco, T. (2012). A simple approach for stochastic generation of spatial rainfall patterns. Journal of Hydrology, 472-473, 63-76, doi:10.1016/j.jhydrol.2012.09.010.

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Giustarini, L., Camici, S., Tarpanelli, A., Brocca, L., Melone, F., Moramarco, T. (2010). Dam spillways adequacy evaluation through bivariate flood frequency analysis and hydrological continuous simulation. In: R.N. Palmer (Ed), World Environmental and Water Resources Congress 2010 - Challenges of Change, American Society of Civil Engineers, Providence, Rhode Island, 2328-2339, doi:10.1061/41114(371)241.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 2089, 2013.