Review of the paper hess-2014-487 - Revised version following first review

"From runoff to rainfall: Inverse rainfall-runoff modelling in a high temporal resolution" by M. Herrnegger, H.P. Nachtnebel and K. Schulz

June 15, 2015

1 General comments

The paper is a re-submission of a paper submitted by the same authors for publication in HESS. The paper describes an innovative approach to inverse rainfall-runoff simulations in order to infer catchment rainfall from runoff observations.
We participated in the review of the prior version of the paper and found that the manuscript is greatly improved compared to the first submission. Key clarifications were added by the authors along with interesting additional modelling experiments.
We believe that the paper can be accepted for publication with minor revisions. However, without requiring another round of review, further clarifications need to be added related to two points:

- The authors must clearly indicate when and why they infer catchment rainfall P_{inv} using a rainfall-runoff model that was calibrated with observed catchment rainfall as an input. This experiment is theoretically interesting but practically useless because if rainfall is the unknown, it cannot be used as an input of the forward model. In that regard, we believe that the experiment $exp5$ is critical because it shows that the method developed by the authors provides reasonable results in the case where the forward model is calibrated with rainfall data that are independent from the observed catchment rainfall. We were very interested by the comparison of results between $exp5$ and $exp3$: the forward model exhibits significantly lower NSE in $exp5$ compared to $exp3$, which is expected because the forward model is driven with the lower quality INCA rainfall in $exp5$. As a result, we expected the model from $exp5$ to be less representative of the catchment dynamic than $exp3$. However, this does not prevent the correlation between Pobs and Pinv to be higher for $exp5$ than $exp3$. This is a counter intuitive result and may call for a few comments.

- It is not clear in the text, especially in section 2.2.1, that there exist situations where the inversion method proposed by the authors is *theoretically* impossible. We are aware of at least one such situation, i.e. when actual evapotranspiration is greater than rainfall within a single time step. In this case, the rainfall evaporates back to the atmosphere completely and we believe there is no way to obtain an inversed estimate from runoff data. If the authors

do not agree with this view, they should demonstrate the possibility of inversion by applying their method to a set of water limited catchments with an aridity index (mean ratio of rainfall over potential evapotranspiration) far lower than 1. We insist on the fact that a method being *theoretically* inapplicable is different from limitations introduced by model structures (e.g. thresholds) or data errors (e.g. uncertainty in streamflow data).

We also regret that the authors did not consider an application of their method to a larger sample of catchments, which could have facilitated the response to the reviewers. However, we understand that this is not a standard practice in the hydrological research community yet. As a result, we do not want to penalise this paper for a more general comment on research methods in hydrology. However, we hope that the greater availability of hydrological data will change this situation in the near future.
Overall, we believe that the clarifications we requested can be addressed by adding several sentences without requiring any more modelling work. Additional detailed comments are provided in the following section.

2 Specific comments

1. Page 1 Line 15, "The only additional information available concerning the precipitation of a catchment is the runoff observation": we suggest replacing this sentence by "Runoff observations constitute a good proxy to precipitation observations with a considerably lower level of associated uncertainty. ''

2. Page 1 Line 18, "a simulated runoff value that corresponds to the observation": We suggest replacing this statement by " a simulated runoff value closely matching the observed runoff".

3. Page 1 Line 19, "also evaluating different model parameter sets": we suggest removing this statement.

4. Page 3 Line 84, "at the 95 % confidence level": please remove this statement. There is no way to attach such a precise probability estimate to generic confidence intervals.

5. Page 4 Line 93, "Two inverse problems can be identified with the forward problem": we suggest replacing this sentence by "Two inverse problems related to this forward problem can be identified".

6. Page 4 Line 105, "integral of rainfall over a certain period, considering evapotranspiration losses and water storage characteristics": we suggest replacing this statement by "integral of rainfall minus evapotranspiration losses and change in water storage over a certain period of time".

7. Page 5 Line 125, "wet catchments are more likely to react as simple dynamical systems": please clarify this statement. What do you mean?

8. Page 6 Line 172 "These functions have a time component, which is indicated by the index t.": Please clarify this statement. First we suggest introducing two different names for the state and output functions (e.g. f and g). Second, if the functions had a time component,

we would expect Equations (2) and (3) to be :

$$S_t = f(S_{t-1}, I_t, t|\theta_i) \quad (1)$$

$$O_t = g(S_{t-1}, I_t, t|\theta_i) \quad (2)$$

In other words, the functions f and g would be dependent off the time variable t, which is the case for non-stationary catchments. We suspect that this is not the intent of the authors. We suggest removing this statement.

9. Page 6 Line 180: Please add at the beginning of the line the statement: "If the function f is invertible, ''. The inversibility of f is a critical assumption to apply the inversion method described in this paper as indicated in lines 274 to 276 , Page 10, and in line 388, Page 13. It must be stated here unambiguously because the structure of many rainfall-runoff models may not satisfy this requirement.

10. Page 8 Line 219, "This is in principally possible": Please change this statement to "In principle, this is possible if the rainfall-runoff equation is invertible". See previous comment.

11. Page 8, Line 244, "For the forward model used here, the differential equations of the linear reservoirs are solved analytically. An internal time step discretization is included in the model code to guarantee, that the transition between system states above and below the threshold value are solved exactly. This is not possible in the analytical solution.": This statement is not clear. Why would a numerical solution provide a better solution than an analytical one? Numerical solutions remain an approximation that always introduce a lack of precision (even if it remains negligible when the numerical scheme is design correctly).

12. Page 15 Line 315, "In a first step 3 different periods are used for calibration of the model parameters": Please indicate that observed catchment rainfall may be used to calibrate the forward model for testing purposes, even if this configuration is not of practical interest (see general comment).

References