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Discussions

Interactive comment on "From runoff to rainfall: inverse rainfall–runoff modelling in a high temporal resolution" *by* M. Herrnegger et al.

Anonymous Referee #2

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1 General comments

The paper by Herrnegger et al. presents a method to derive estimates of rainfall from runoff and potential evapotranspiration by inversing a rainfall-runoff model. The paper is clearly written and well presented, it deals with a very interesting topic and the authors have covered several important issues related to the method presented including the impact of model initialisation, model calibration and validation. However, we believe that the method requires significant improvements before the paper can be accepted for publication. Three points require the author's attention:

- Inversibility of the state-space equation: the method presented by the author is based on the inversion of the state-space equation presented in Equation 4. The authors have not fully explored the fact that the relationship may not be inversible in certain conditions. They have mentioned inversibility problems related to snow pack and distributed modelling in section 2.2.1. However, we believe that this problem is far more common that suggested by the authors, due to the two following issues:

- Thresholds: many rainfall-runoff model structures use threshold functions to process input data. For example the COSERO model relies on three min/max operators in equation A1, A2, A3 and A5. These functions introduce discontinuities in the relationship between rainfall and runoff preventing an inversion algorithm to be applied. A simple example can be given with the interception reservoir of the COSERO model: in equation A1, $BWI_t = 0$ whatever value of rainfall R_t is chosen such as $R_t < ETP_t - BWI_{t-1}$, as a result the state space equation related to the particular state BWI_t is not inversible for low rainfall values. This example illustrates the difficulty of inversing rainfall-runoff models during low rainfall periods or in high evaporation catchments.
- Delayed responses: Equation 1 assumes that the runoff at time step t is a function of inputs during the same time step (i.e. R_t). However, many rainfall-runoff model structures (e.g. HBV with the MAXBAS parameter) introduce a lag effect between inputs and outputs. As a result, Equation 1 could be rewritten $Q_t = f(R_t, R_{t-1}, R_{t-2}, ..., R_{t-n}, ETP_t, S_{t-1}, \theta_i)$. In this case, it is not clear how the inversion algorithm works because it has to deal with rainfall values at several time steps simultaneously.

Overall, we believe that the inversion method as presented by the authors is possible in many situations, but requires a clear definition of feasibility conditions. This point could be explored in the synthetic experiments. In addition, it is clear that inversion is impossible in certain conditions (e.g. dry spells, high evaporation

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catchments,...), it would be useful for the authors to provide more context on the intended use of the method to judge if these limitations pose a real challenge to be explored further.

- Impact of rainfall-runoff model structure: The method presented by the authors heavily relies on a single rainfall-runoff model (COSERO). As a result, it is not possible to differentiate the impact of the inversion method itself from the one of the rainfall-runoff model. We suggest adding at least another rainfall-runoff model and check the link between the performance of the forward model and results obtained by the inversion method.

- Limited scope of the catchment dataset: all results presented cover a single catchment of 38 km^2 for a period of 3 years. It is extremely difficult to generalize this setup to other hydrological conditions and we urge the authors to consider a larger number of catchments with longer simulation periods. Problems like non-stationarity, poor data quality, prolonged spin-up periods and model biases need to be factored in the results for the method to become relevant to the hydroligical community. We are aware that getting hourly data is not simple for large catchment samples, but the study could be performed at the daily timestep with equally interesting outcome.

Detailed comments are provided in the following section.

2 Specific comments

1. Page3 Line9, “Errors are considerably lower compared to rainfall”: This is certainly true, however the authors process the streamflow data via a non-linear inverse model that could easily magnify streamflow errors by several order of magnitude. I suggest a comment on this point.

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2. Page6 Eq 5 : Please add the objective function that was used in the root-finding algorithm (e.g. squared error). I presume that equation 5 is essentially a stop criteria for the algorithm.
3. Page7 L17, “Reservoir without memory” : I don’t understand this statement. Please clarify and give examples.
4. Page7 L22, “small errors ... can be amplified” : This statement confirms that small errors in streamflow data can back propagate within the inverse model and heavily influence the rainfall estimates. We suggest adding an experiment testing this assumption.
5. Page13 L10, “model performance expressed by the correlation coefficient” : Please add also bias of model simulations. Bias is sometimes difficult to reproduce, especially if the model is calibrated with NSE objective function.
6. Page20 L4 : What is the effect of BWI_t to the rest of the model? I can’t see it mentioned in subsequent equations. Please clarify.
7. Page20 L6 : Is it really $PEX2$ or $f(PEX2)$ that should be mentioned in equation 2 with f the function displayed in Figure A1? Please clarify.
8. Page26 Tab 2 : I presume that the upper and lower values of the TAB and TVS parameters vary with the time step. Otherwise, we could get α and β parameters greater than 1, which could lead to negative values of BW_i. Please clarify.
9. Page31 Figure 9 : Scatter plots are extremely misleading for flow data because of the high concentration of point in the lower left corner. Please change both axis to log scale to get a better distribution of values along the axis.
10. Page33 Figure 11: Same comment than #9.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 13259, 2014.