Response to comments of Anonymous Referee

We would like to thank Dr. McIntyre for the thoughtful comments and suggestions. The follows are our response in regard to the comments and suggestions.

1. I can query the derivation of Eq. 8 from 7b: the right hand side of 7b also needs divided by 'a'? Therefore, the authors should re-inspect the accuracy of this and all equations.

Response

a. Yes, the right hand side of Eq. (7b) is divided by "a" on the derivation of Eq. (8). However, the term "-1/a" is absorbed within $\xi(t)$, a purely random (white noise) process, in Eq. (8). We have double-checked that Eq. (8) was copied correctly from Vanmarcke (1983).

b. All equations have been checked again. They are correct.

Vanmarcke, E.: Random Fields: Analysis and Synthesis, MIT Press, Cambridge, Mass, 1983.

2. The practical value is limited by the assumptions. In particular the method is only applicable to storm events in catchments where the linear rainfall-runoff relationship suffices. The realism of the AR rainfall model is questionable. No validation is attempted, in fact no time-series results are shown, so it's difficult for the reader to judge whether or not the results are plausible. No critical discussion of applicability is provided.

Response

a. The linear reservoir models have been widely used in field situations. Please refer to the response to Comment 3.

b. A brief discussion of applicability of lumped linear reservoir models has been added on page 5 (Line 106) as

> "An ungauged basin is one with inadequate records of hydrological observations at the appropriate spatial and temporal scales which are acceptable for practical applications. It therefore may not be possible to make accurate predictions of the response of ungauged catchment areas at the required resolution. In such circumstances of scarce available data, lumped conceptual models in prediction of runoff are preferred over the distributed hydrological models (e.g., Littlewood, 2002; Khan et al., 2011; Prieto Sierra et al., 2013). In addition, linearity involved in modelling of the rainfall-runoff response of a catchment increases with the catchment area

(Minshall, 1960; Wang et al., 1981; Sivapalan et al. 2002), implying that the assumption of a linear reservoir prevails in large catchments."

Littlewood, I. G.: Improved unit hydrograph characterisation of the daily flow regime (including low flows) for the River Teifi, Wales: towards better rainfall-streamflow models for regionalisation, Hydrol. Earth Syst. Sci., 6(5), 899-911, 2002.

Khan, S. I., Adhikari, P., Hong, Y., Vergara, H., Adler, R. F., Policelli, F., Irwin, D., Korme, T., and Okello, L. Hydroclimatology of Lake Victoria region using hydrologic model and satellite remote sensing data. Hydrol. Earth Syst. Sci., 15(1), 107-117, 2011.

Minshall, N. E. Predicting storm runoff on small experimental watersheds, J. Hydraul. Div. Am. Soc. Eng., 86(HYB), 17-38, 1960.

Prieto Sierra, C., García Alonso, E., Mínguez Solana, R., and Medina Santamaría, R. Proposal of a lumped hydrological model based on general equations of growth- application to five watersheds in the UK, Hydrol. Earth Syst. Sci. Discuss., 10, 9309-9361, 2013.

Sivapalan, M., Jothityangkoon, C., and Menabde, M. Linearity and nonlinearity of basin response as a function of scale: Discussion of alternative definitions, Water Resour. Res., 38(2), 1012, 2002.

Wang, C. T., Gupta, V. K., and Waymire, E. A geomorphologic synthesis of nonlinearity in surface runoff, Water Resour. Res., 17(3), 545-554, 1981.

c. As indicated in the literature (on page 3 of the manuscript), some rainfall events do show linear dependence on its own previous values and on an imperfectly predictable term. Therefore, the assumption of an AR rainfall model is not restrictive.

d. The important feather of the stochastic approach presented here is that it provides a variance relationship for the dependent variable, i.e., a quantitative measure of uncertainty in applying the deterministic (or mean) model, at which direct observations of the dependent variable are not available. Therefore, instead of an illustration of real time-series results, a figure (namely, Figure 3) is added to demonstrate is its essentially predictive character over a relative large time scale on page 13 (Line 258) as

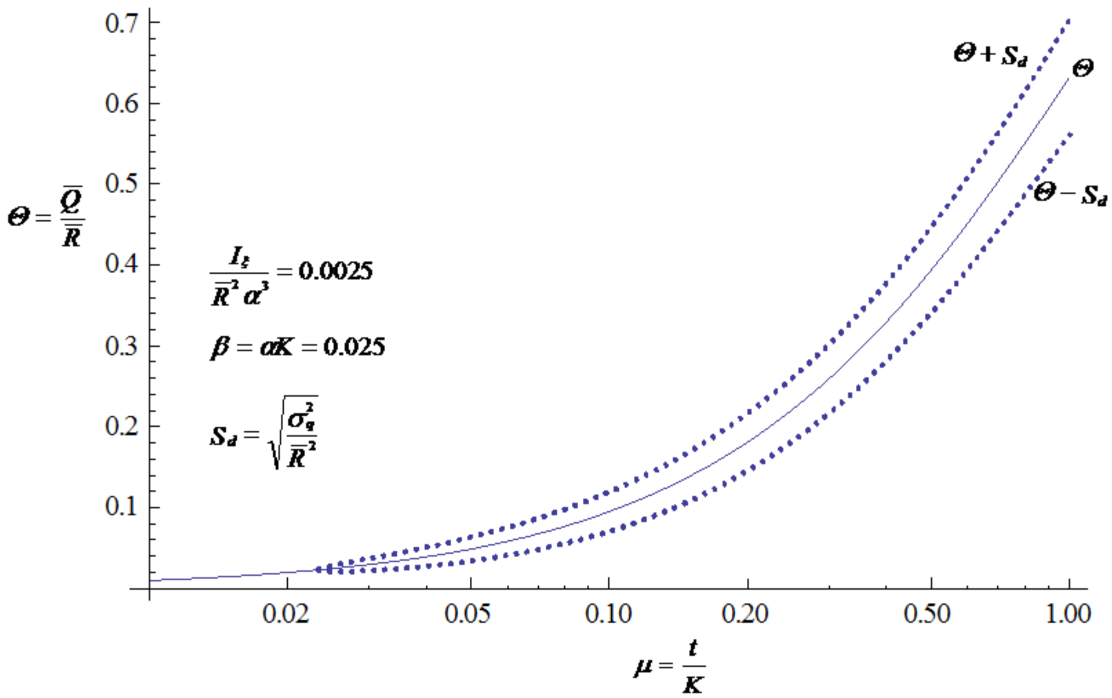

Figure 3. Normalized mean runoff discharge profiles along with one standard deviation intervals as a function of dimensionless time.

3. I note the comment of the first reviewer that there is no mention of some of the classical work on linear rainfall-runoff modelling, and certainly the technical note should be put in context of these established methods.

Response

As suggested, the work on linear rainfall-runoff modelling has been noted on page 4 (Line 90) as

> "The origin of deterministic modeling of rainfall-runoff processes dates back to the unit hydrograph concept developed by Sherman (1932). Introduction of the theory of linear systems with the unit hydrograph concept leads to the theory of the instantaneous unit hydrograph (IUH) by Nash (1957) under the assumption that watershed behavior can be associated with a cascade of linear reservoirs and then the generalized unit hydrograph theory by Dooge (1959) under the assumption that basin response can be represented by a cascade of linear channels and linear reservoirs in series. There were also attempts to quantify the runoff discharge involved the concept of IUH (e.g., Rodriguez-Iturbe and Valdes, 1979; Pegram and Diskin, 1987; Chutha and Dooge, 1990; Bhunya et al., 2003). On the other hand, single linear reservoir models have also been used for, for example, modeling discharge from glacierized catchments (e.g., Hannah and Gurnell, 2001), evaluating the interception process during rainfall (e.g., Hashino et al., 2002), quantifying the

impact of changes in land use (e.g., Buytaert et al., 2004), computing the temporal rates of sediment discharge from a rainfall event (e.g., Tyagi et al., 2008), and describing streamflows forced by rainfall sequences (e.g., Suweis et al., 2010)."

Bhunya, P. K, Mishra, S. K., and Berndtsson, R. Simplified two-parameter gamma distribution for derivation of synthetic unit hydrograph, J. Hydrol. Engng., 8(4), 226-230, 2003.

Buytaert, W., De Bièvre, B., Wyseure, G., and Deckers J. The use of the linear reservoir concept to quantify the impact of changes in land use on the hydrology of catchments in the Andes, Hydrol. Earth Syst. Sci., 8(1), 108-114, 2004.

Chutha, P., and Dooge, J. C. I. The shape parameters of the geomorphologic unit hydrograph, J. Hydrol., 117(1-4), 81-97, 1990.

Dooge, J. C. I. A general theory of the unit hydrograph, J. Geophys. Res., 64(2) 241-256, 1959.

Hannah, D. M., and Gurnell, A. M. A conceptual, linear reservoir runoff model to investigate melt season changes in cirque glacier hydrology, J. Hydrol., 246(1-4), 123-141, 2001.

Hashino, M., Yao, H., and Yoshida H. Studies and evaluations on interception processes during rainfall based on a tank model, J. Hydrol., 255(1-4), 1-11, 2002.

Nash, J. E. The form of the instantaneous unit hydrograph, IAHS Publ., 45,112-121, 1957.

Pegram, G. G. S., and Diskin, M. H. A study of cell models: 1. A manifold cell model for distributed surface runoff systems, Water Resour. Res., 23(4), 646-654, 1987.

Rodriguez-Iturbe, I., and Valdes, J. B. The geomorphologic structure of hydrologic response, Water Resour. Res., 15(6), 1409-1420, 1979.

Sherman, L. K. Stream Flow from Rainfall by the Unit Graph Method, Eng. News Rec., 108, 501-505, 1932.

Suweis, S., Bertuzzo, E., Botter, G., Porporato, A., Rodriguez-Iturbe, I., and Rinaldo, A.: Impact of stochastic fluctuations in storage-discharge relations on streamflow distributions, Water Resour. Res., 46(3), W03517, 2010.

Tyagi, J. V., Mishra, S. K., Singh, R., and Singh, V. P. SCS-CN based time-distributed sediment yield model, J. Hydrol., 352(3-4) 388-403, 2008.