Hydrology and Earth System Sciences Discussions

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Interactive comment on "A stochastic approach for the description of the water balance dynamics in a river basin" *by* S. Manfreda and M. Fiorentino

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Received and published: 7 July 2008

First of all, we would like to thank the three reviewers for their efforts in stimulating a constructive discussion on the present paper and also outlying some unclear points that need to be discussed in order to help the readers. Suggestions have been taken into consideration and the paper has been significantly modified in order to accomplish reviewer's requests.

As a general remark, the present paper was thought to introduce the theoretical framework for the derivation of the soil water balance at the basin scale using the hypothesis of heterogeneous soil water storage capacity. An application of the model with the derivation of the runoff dynamics and probability distributions derived at the steady state is presented in the paper by Manfreda (2008). Nevertheless, we have included in the present paper a validation of the model using a comparison with the results of a

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long term simulation performed with a distributed model.

All referees agree on one point that is the need to clarify the notation within the text. For this reason a new section will be included providing a description of the notation.

We will try to give an overview of the modifications introduced into the paper considering point by point all the comments of the referees.

1 Response to Reviewer 1

P1) Regarding this point, we have modified the text of the paper explaining the role of the semi-empirical parameters b and w_{max}. One of this two parameters may depend on topography as exposed by Chen et al. (2007). For this reason, the first paragraph of page 2 has been modified as follow: "...The above distribution has been extensively used in several conceptual model where the parameters b and w_{max} have been calibrated against runoff data. In a recent work, Chen et al. (2007) outlined that the above expression can be estimated directly from digital elevation data. In particular, they use the spatial distribution of the TOPMODEL topographic index ($W_I = ln(a/tan\beta)$) (Beven and Kirkby, 1979) to estimate the so called index of runoff generation difficulty ($IRDG = (max[W_I] - W_I)/(max[W_I] - min[W_I])$) through a normalized function of the topographic index as suggested by Gou et al. (2000). Specifically, the authors propose to substitute the parabolic curve of soil water storage capacity of the Xinanjiang model with the cumulative frequency distribution of IRDG. Under this hypothesis one can estimate the shape parameter b can be calibrated by fitting the parabolic curve of the Xinanjiang model (equation 2) with the cumulative frequency distribution of IRDG, while the parameter w_{max} needs to be calibrated."

Finally, the probability distribution derived in the paper are the distribution of "s", but also of "a" that represent a derived variable related to soil moisture dynamics and that provides a preliminary description of the basin attitude to runoff production.

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P2) This advice has been taken into account rearranging the section where the model is described and also including a new section for the notation.

P3-P4) The model includes a number of approximations in order to get an analytical expression of the basin dynamics. Among them, we used uniform rainfall, a parabolic distribution for soil water storage capacity, etc. Some of those assumptions were used by several authors in previous works and for this reason were not discussed or justified, for others a justification may help and improve the readability of the paper. Nevertheless, the present paper was written with the intend to present mainly the theoretical work while a second paper will also present an application of the model. In particular, the paper by Manfreda (2008) will present an application of the model where the ability of the model to predict the runoff dynamics is tested. Nevertheless, the comment of the referee was taken into account also in this paper and for this reason a new graph has been included in the last part of the paper were the probability distribution of saturated areas obtained from an hydrological continuous simulation with a semi-distributed model are tested against the theoretical distributions obtained from the proposed theory.

2   Response to Reviewer 2

I would like to thank the reviewer 2 for his encouraging comments. He suggested to clarify the meaning of some symbols used in the paper and also the better address the relevance of rainfall spatial distribution in the water balance. We totally agree with this review and the specific comments will be addressed in the revised version of the paper.

P1) The assumption of uniform rainfall is certainly an approximation of the model that may affect its performance both in large basins and also in arid and semi-arid environments. At the present stage, the model was thought to be applied in humid environments and small-medium size basins. We did not discuss the application in arid

region with heterogeneous rainfall because the model was not conceived for this environment. In case of arid environment, we would suggest to use the model proposed by Rodriguez-Iturbe et al. (2006) that was designed in order to account for the spatial heterogeneity of rainfall and vegetation in a flat landscape.

Nevertheless, the following sentence was introduced at the end of the rainfall model section: "The climatic conditions may also affect the spatial correlation and extend of rainfall fields that become more uniform in humid regions."

P2) Equation 2 is correct. "W" represents the soil water storage capacity at a point.

P3) The model uses the same concepts of the Xinanjiang model. The paragraph has been modified in order to avoid misleading messages in the paper.

P4) I agree that definition given in equation 4 along with the use of the parameter nZr is misleading and useless for model comprehension so it has been removed from the paper.

P5) Wt is the total water content in the soil and wm_t is the level of the water in the parabolic bucket that represent the basin.

P6) This point is unclear to me, but if the referee refers to the variable ξ this last was introduced to describe the relative soil saturation at a point while s is the average soil saturation of the schematic basin. Equation 5 has been modified in the following:

$$L(\zeta) = V\zeta(t, x), \tag{1}$$

P7) The word "to remark" has been removed.

P8) Equation 11 was changed removing the second term on the right.

P9) Actually, the equation is already normalized by w_{max}, because the parameter $\beta = V/w_{max}$.

3 Response to Reviewer 3

P1) The present paper introduced a new stochastic model conceived at the basin scale to represent the soil water balance dynamics.

P2) The use of a parabolic function is adopted in order to mimic the behaviour of a humid basin where the unsaturated zone of the soil varies across the basin according to the relative position within the basin. In fact, the research of Chen et al. (2005) shows that the shape of the parabolic curve depends on the topography of the basin.

P3) Regarding this specific point, it is necessary to remark that the runoff was not neglected. In fact, it is generated for saturation excess from the portion of the schematic basins that becomes saturated. In the soil water balance, the infiltration is equal to the rainfall depth as long as the soil gets saturated. This point has been clarified in the reviewed version of the paper and also in order to avoid confusion the Y as been changed with I.

P4) The model adopts scheme proposed by the Zhao's model so the soil water content is assumed to fill the soil with $W \geq wm_t$ in the remaining part of the basin the soil will remain saturated. This point was unclear in the first version of the paper and has been modified in the new version of the paper.

P5) It is indeed a good result the fact that the numerical simulation provides a good agreement with the theoretical curves because we have an important approximation in the definition of the soil water losses function that may affect the results. In order to clarify this point the following sentence has been introduced at the end of the paragraph: "8230;This result provides an idea of the errors associated with the use of an approximated function to describe the soil water losses (see equation 9)."

P6) I agree with the referee on this point because, rainfall effects have not been investigated. This point have been addressed including new graphs that describes the role of the parameters α and λ on the probability distribution of s and a.

P7) The emphasis of the paper is mainly on the role of the parameters describing the soil and basin characteristics that is the novelty of this work. It is true that those are semi-empirical parameters. The text has been modified accordingly.

4 References

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