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Hydrology and Earth System Sciences Discussions

Interactive comment on "A mass conservative and water storage consistent variable parameterMuskingum-Cunge approach" *by* E. Todini

Anonymous Referee #2

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The paper addresses a topic, which is often tackled in the hydrologic community, since questions connected to hydrologic flood routing with the Muskingum model belong to the evergreens of scientific and operational hydrology. The original lumped Muskingum flow routing model was introduced by McCarthy in 1938. It is very popular since it is simple and easy to use in practice. The model parameters of the original version, however, must be calibrated using data on the inflow and outflow hydrographs. In the Muskingum-Cunge method (MC) from 1969, the resultant equations are similar to the traditional Muskingum method and the parameters do not have to be calibrated but can be determined from channel characteristic features instead. Many papers were published on this method; the reviewed research etude reacts to the fact that the variable

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parameter MC method does not fully preserve the mass balance in the modeled river reach (this may not be negligible, since it has been shown that under certain conditions it can reach values up to 8 to 10%). The paper reconsiders the derivation of the MC method and suggests modifications needed to allow the MC to fully preserve the mass balance which also comply with the original Muskingum formulation. The paper builds on results from previous papers published on the topic and, given that the amount of literature published in connection with the Muskingum model is huge and an overview is almost impossible to be made, it of goes directly back in history with respect to the problem tackled. The results published in these papers were extended in two items: The first one is the inconsistency of the MC method, which relates to a mass balance error. For this problem, a conclusive and convincing explanation has been offered in the paper. It is shown that problem with the mass balance is caused by the way how time variant parameters in the MC method were introduced, which seem to be in conflict with the assumptions posed in the original derivation of the Muskingum scheme. The second one is a paradox in the variable parameter MC approach. It was shown in the paper that two different and inconsistent values for the water volume stored in the channel are obtained, when using both equations in parallel. The paper offers an explanation for the two inconsistencies and shows appropriate corrections. When testing the suggested improvements, the positive effect of the pressure term inclusion into the MC method by Cappalaere was demonstrated together with the validity of the new equations by routing synthetic flood waves through hypothetical three channels with different cross sections (rectangular, triangular and trapezoidal), with varying the slope, roughness and space and time integration intervals. Overall, an additional improvement of the model dynamics was achieved and demonstrated without the undesired inconsistency in the mass balance and in compliance with the original Muskingum equations when compared to the solutions using the full de Saint Venant equations. The assumptions of the research were clearly outlined; the treatment of the subject in the paper is straightforward, parsimonious and systematic. The results are based on clear argumentation; the presented concept is compared to other methods

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under synthetic “numerical laboratory conditions”. The presented results support the interpretations and conclusions under the given conditions. The solution can therefore be considered as an extension of the MC method. The complete acknowledgement of the results by fellow scientists (traceability of sources) would be rather difficult to guarantee given the large popularity of the method. In this respect sufficient credit to related work was given (maybe one or two additional citations could have been added) and the author clearly indicates his own contribution. The title clearly reflects the contents of the paper and the abstract provides a concise and complete summary. The amount and quality of the supplementary material is appropriate. A few changes, which are given below, could add to the interpretability of results. The overall presentation is well structured and clear and the language is fluent and precise.

Section addressing individual scientific questions/issues ("specific comments"):

Maybe it would be worth considering, for the sake of comprehensiveness, to give a few remarks on other papers, where the method has also received critical treatment, such as the problem of the negative dip of the impulse response, etc. (although it is not really within the scope of the paper).

The description of the MC method could be made a bit more self-contained (especially for the generation of younger hydrologists) by giving a few more details on the derivation of the MC method (page 1556), e.g. like it is given in Wang et al. (2006).

Figure 4 contains references to the MCT method; this was not introduced in the text at the time of first referencing to the figure.

A few hints, under which natural conditions in rivers the suggested improvement could reward users with higher accuracy of simulations or forecasts could be useful for those, who would hesitate reprogramming their software.

References Wang, G.T., Yao Ch., Okoren C., Chen S.: 4-Point FDF of Muskingum method based on the complete St Venant equations Journal of Hydrology 324 (2006)

339-349.

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