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Hydrology and Earth System Sciences Discussions

Interactive comment on "Temporal dynamics of hydrological threshold events" *by* G. S. McGrath et al.

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We would like to thank the reviewers for taking their time to provide comments and suggestions to improve the manuscript. In reply we would like to first re-iterate the theme of the paper and then, with that as context, respond to some of the criticisms and suggestions.

In this paper we relate the pattern of the occurrence of threshold triggered flow processes i.e. the statistical properties of the timing and magnitude of such events, to the pattern (the statistical properties) of the timing and magnitude of rainfall. We compare and contrast the resulting patterns which result from a simple rainfall intensity threshold and simple storage threshold. The principal innovation of this paper is to develop

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the foundation of a general theory for how the temporal structure of flow processes which are triggered by thresholds emerges from the climate signal. In contrast to current approaches which describe hydrological processes as continuous time series, the approach here focuses on statistical descriptions of discrete events. This is because threshold processes do not occur continuously in time but are active episodically, driven by rainfall. Therefore it is natural to ask how the temporal structure of such events is related to that of the rainfall.

The second innovation comes from the recognition that for many hydrological processes we often can only measure part of the process. For example, we can measure the episodic delivery of pesticides through lysimeters. This temporal structure, as revealed by the breakthrough curve, is often the best we can say of the preferential flow process which delivered the pesticide to the sampling device. The flux of water through preferential flow cannot currently be measured directly at all the relevant scales for us to make better predictions for pesticide risk assessment. What we can measure however is the temporal pattern of triggering from the pesticide breakthrough curve and perhaps also the level of soil moisture which may be associated with preferential flow triggering. Therefore in this paper, for the first time, we inter-relate the statistical properties of the temporal dynamics, soil moisture and the flux to begin to establish how one observation may relate to the rest of the 'hidden' dynamics. This is in essence a similar philosophy as taken by Rundel et al. (this issue) in their approach to the prediction of earthquakes, where the underlying dynamics are also highly nonlinear, threshold like.

In summary the major scientific criticisms identified from the reviews relate to:

- the limitations of the analytical approach and the assumptions used outweigh the outcomes
- the lack of applicability
- the lack of validation of results

HESSD

3, S1892–S1895, 2007

In response we consider the above criticisms should be addressed by future research and are beyond the scope of this paper. More specifically:

- The purpose of the paper is to begin to develop a general understanding of the relationship between rainfall and flow event triggering. As a number of hydrological processes have similar threshold triggers to rainfall intensity and/or water storage there is the potential for results to be applicable to a variety of fields including those concerned with erosion, interception, subsurface flow and pesticide risk assessment. It is therefore natural to keep the processes simple to afford some generality of results.

- The approach required simplicity of climate and process descriptions to allow for analytical tractability and to make interpretation of results more straight forward. It is very unlikely that the relationships as we derived them would have been discovered by numerical analysis as one would have to have a clear hypothesis in mind to do the numerical analysis. We have chosen generality from the analytical approach at the expense of a more detailed process description. This is a valid approach to derive patterns that can be used to provide hypotheses for experimental studies.

- In relation to the assumptions adopted for the triggering processes, the storage and intensity thresholds, we expect real triggering to display a mixture of the two types of triggering identified here. Because of the simplicity of our approach we have a basis to now hypothesise what the temporal dynamics of more complex processes may look like.

- To our knowledge this was the first shot at the problem within a hydrological context. For that reason there was a need to make the many simplifying assumptions as there was no existing theory with which to make and test hypotheses of more complex problems.

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3, S1892–S1895, 2007

- We acknowledge that there are numerous limitations associated with the assumptions and their validity but these need to be addressed by a refinement of the work presented here in future research. We agree we could better discuss these limitations in the text and this has been adjusted accordingly.
- In response to the criticism that this was a nice theoretical exercise but far from being applicable we would like to reiterate the point that the theory developed here, despite its limitations, can now form the basis for developing and testing hypotheses for future modeling and empirical studies of episodic hydrological processes. For example, we are currently applying the theory to develop a better understanding of the risk of pesticide transport by preferential flow.
- At this stage there is no validation of the approach, firstly because it is new, and secondly a significant empirical investigation is required which is beyond the scope of this paper.

Almost all the technical suggestions are agreed en mass are will not be listed here but addressed in the final manuscript if requested. Responses to specific reviews are made separately.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 3, 2853, 2006.