Fully integrated modelling of surface-subsurface flow processes: quantifying in-stream and overland flow generation mechanisms.

by
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Contents

Abstract

The understanding and effective management of flood and drought issues within catchments, are critical to sustaining such systems and the environments they support. Surface water and groundwater systems within catchments exhibit important feedbacks and therefore must be considered as a single resource. Holistic consideration of these systems in catchment hydrology requires the understanding and quantification of both surface and subsurface flow processes and their interactions. This requires that the physics driving the interactions/processes are well understood. Consequently, a need has arisen for physics-based models that can aid in building intuition about these interactions/processes, and also assist in quantifying these interactions/processes. In the last decade, physics-based fully integrated surface-subsurface flow models have become an important tool in understanding and quantifying flow generation processes and surface-subsurface interactions. However, due to the relatively short history of fully integrated models, the analysis and interpretation of outputs is often incommensurate with the spatiotemporal information within the outputs. A key shortcoming of these models is the inability to use model outputs to properly analyse and interpret flow generation mechanisms and surface water-groundwater interactions with respect to the streamflow hydrograph.

In this research, a new Hydraulic Mixing-Cell (HMC) method for quantifying in-stream and overland flow generation mechanisms within physics-based models of surface-subsurface flow is developed. The HMC method is implemented and tested within the fully integrated surface-subsurface flow model code HydroGeoSphere. The HMC method is used in a series of applications to quantify the contributions to total streamflow of groundwater discharge to the stream and hillslope, and direct rainfall to the stream and hillslope.

Application of the HMC method to a hypothetical catchment is used to investigate the importance of in-stream flow travel time and losses. Results showed that it is necessary to account for in-stream travel time and stream losses in order to accurately quantify the contribution of groundwater to streamflow. The HMC method is then used with another hypothetical catchment model to investigate the potential error in 10 commonly used automated baseflow separation methods.

Simulations with a range of hydrological forcing, soil characteristics and antecedent moisture conditions showed the potential error to be significant for these automated methods; this warrants caution in overvaluing their outputs. Finally, the HMC method is employed in a case study of the Lehstenbach catchment, which included a model of a riparian wetland and catchment. Application of the HMC method in this case study was used to investigate wetland and catchment processes through separation of streamflow hydrographs and spatiotemporal analysis of flow generation mechanisms. This analysis elucidated the dynamics of overland and in-stream flow generation processes. This research has opened up a new way of analysing and interpreting flow generation mechanisms using fully integrated surface-subsurface flow models. The analysis and interpretation techniques implemented in this thesis form the basis for comprehensive analysis of outputs from physics-based modelling of catchment hydrological processes.

Statement of Originality

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List of works:

Partington, D., P. Brunner, C. T. Simmons, R. Therrien, A. D. Werner, G. C. Dandy, and H. R. Maier. 2011. A hydraulic mixing-cell method to quantify the groundwater component of streamflow within spatially distributed fully integrated surface water - groundwater flow models. *Environmental Modelling and Software*, 26:886-898.

Partington, D., P. Brunner, C. T. Simmons, A. D. Werner, R. Therrien, G. C. Dandy, and H. R. Maier. 2012. Evaluation of outputs from automated baseflow separation methods against simulated baseflow from a physically based, surface water-groundwater flow model. *Journal of Hydrology*, 458-459: 28-39.

Partington, D., P. Brunner, S. Frei, C. T. Simmons, R. Therrien, A. D. Werner, H. R. Maier, G. C. Dandy, J. H. Fleckenstein. Interpreting flow generation mechanisms from integrated surface water-groundwater flow models of a riparian wetland and catchment. Submitted to *Water Resources Research* on 9 November, 2012.

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