Geophysical Research Abstracts
Vol. 19, EGU2017-9261-1, 2017
EGU General Assembly 2017

An evaluation of Dynamic TOPMODEL in natural and human-impacted catchments for low flow simulation

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Models of catchment hydrology are essential tools for drought risk management, often providing input to water resource system models, aiding our understanding of low flow processes within catchments and providing low flow simulations and predictions. However, simulating low flows is challenging as hydrological systems often demonstrate threshold effects in connectivity, non-linear groundwater contributions and a greater influence of anthropogenic modifications such as surface and ground water abstractions during low flow periods. These processes are typically not well represented in commonly used hydrological models due to knowledge, data and model limitations. Hence, a better understanding of the natural and human processes that occur during low flows, how these are represented within models and how they could be improved is required to be able to provide robust and reliable predictions of future drought events.

The aim of this study is to assess the skill of dynamic TOPMODEL during low flows for both natural and human-impacted catchments. Dynamic TOPMODEL was chosen for this study as it is able to explicitly characterise connectivity and fluxes across landscapes using hydrological response units (HRU's) while still maintaining flexibility in how spatially complex the model is configured and what specific functions (i.e. abstractions or groundwater stores) are represented. We apply dynamic TOPMODEL across the River Thames catchment using daily time series of observed rainfall and potential evapotranspiration data for the period 1999 – 2014, covering two major droughts in the Thames catchment. Significantly, to assess the impact of abstractions on low flows across the Thames catchment, we incorporate functions to characterise over 3,500 monthly surface water and ground water abstractions covering the simulation period into dynamic TOPMODEL. We evaluate dynamic TOPMODEL at over 90 gauging stations across the Thames catchment against multiple signatures of catchment low-flow behaviour in a 'limits of acceptability' GLUE framework. We investigate differences in model performance between signatures, different low flow periods and for natural and human impacted catchments to better understand the ability of dynamic TOPMODEL to represent low flows in space and time. Finally, we discuss future developments of dynamic TOPMODEL to improve low flow simulation and the implications of these results for modelling hydrological extremes in natural and human impacted catchments across the UK and the world.