Geophysical Research Abstracts
Vol. 19, EGU2017-13973, 2017
EGU General Assembly 2017

Can complex subsurface water fluxes be represented at the catchment scale within a (relatively) simple modeling framework?

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In this work, we explore the time- and spatial-scales for which a simpler conceptual model could possibly reproduce the water fluxes dynamics as derived from the common 1-dimensional and 2-dimensional solution to Richards' equation. In fact, the spatial and temporal heterogeneity of hydrological fluxes in the vadose zone creates a considerable challenge in understanding the water cycle at the catchment scale, and whilst many models describe the water fluxes at various scales, a simple water balance fails to discretise the fluxes in the vadose zone when a unit hydraulic gradient cannot be assumed. In this case, solving analytically or numerically the fully transient and highly non-linear Richards' equation is essential for small hillslope, field or catchment scales. Such approaches, however, are not efficient and may not represent the dominant controls at larger catchment or regional scales. In particular, while the absolute value of the fluxes may not be reproduced accurately, the short-term (hourly to daily) and long-term (annual) dynamics describing the relationship between the catchment-scale hydrological inputs such as precipitation, irrigation and evapotranspiration, and the water fluxes within the vadose zone, at the root-depth, may be well described. As part of a Critical Zone Observatory project focusing on red soils in China, we use basic long-term soil and hydrology data recorded in an agricultural catchment and compare the model-derived catchment-scale response in terms of soil moisture and streamflow based on the fully transient modelling approach with the HYDRUS software and a simpler conceptual model we develop for that purpose.