Geophysical Research Abstracts,
Vol. 11, EGU2009-14071, 2009
EGU General Assembly 2009

Where does water go when it rains? Conceptualizing runoff processes in headwater catchments (John Dalton Medal Lecture)

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Streamflow generation concepts have remained largely unchanged since the First International Hydrological Decade (1965-1974) despite numerous case studies from an ever-widening array of catchments. Two broad classes of streamflow generation behavior have been described and conceptualized into widely used model structures: infiltration excess overland flow and saturation excess overland flow. These concepts rely on the description of spatial patterns of soil surface infiltration rates and "variable source areas" of saturation (from rising near-stream water tables) with known boundary conditions. While subsurface flow during storm events occurs (and in steep wet areas may greatly exceed overland flow contributions), its location and behavior are poorly conceptualized and predicted. The mechanisms of subsurface flow delivery to the stream are seemingly endless and range from lateral preferential flow, to flow along impeding layers, to flow in highly conductive soil and sub-soil layers—all largely unpredictable from conditions at the soil surface. So how can we conceptualize subsurface flow and its many manifestations and such poorly known boundary conditions? Can we simplify the myriad subsurface response mechanisms to be consistent with infiltration excess and saturation excess overland flow concepts? This talk examines the future of runoff conceptualization and advances a simple concept of subsurface "storage excess". I offer evidence in support of storage excess using field data from catchments distributed across a wide array of climate, geology, vegetation and topographic conditions. These data show subsurface storage filling and then spilling is a simple concept that makes sense across many scales and may help explain runoff amount and timing, geographic and time source components, and residence time. I address how such measures might be used for "gauging" the ungauged catchment as part of the IAHS Decade on Prediction in Ungauged Basins (2003-2012) and informing questions of "what to measure, in what order and why"?