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Why is predicting hydrologic catchment response so complicated?

We observed ten sub-catchments over the course of three monsoon seasons in order to determine what controls their hydrologic response behavior. The hillslopes reacted very differently in each of the seasons. During the first season, soil depth correlated best with mean transit time, during the second season hydraulic conductivity appeared to be the main cause for differences in mean transit time and in the third season, the control shifted towards topographic parameters. The shift in controls could only be explained by the differences in external forcings we observed. The precipitation patterns and amounts were distinctly different in all three monsoon seasons causing different hydrologic states in the catchments and activating different dominant flowpaths. During the first monsoon season a series of heavy storms at the beginning of the season filled the available water storage in the soils and triggered fast flowpaths (macropore and overland flow) sooner or later depending on the soil depth. In the second monsoon season the precipitation events were more scattered in time and due to evapotranspiration the full capacity of the soil storage was never reached. Therefore the dominant flowpaths were restricted to interflow at the soil-bedrock interface and a catchment responded sooner or later depending on the hydraulic conductivity of the soils. Finally, in the last monsoon season the total amount of precipitation was very low and hardly any of the incoming water made it all the way to the catchment outlet. Instead, the water at the outlet consisted mainly of older water from the bedrock aquifer so that the catchments responded sooner or later depending on topographic parameters like mean slope and curvature. From these observations it became clear that determining simple response controls is not going to be feasible. Instead, it is necessary to account for the hydrologic state of the catchment prior to an event because that state has great influence on determining which dominant flowpaths will be activated by a given precipitation event. We developed a dimensionless number that comprises information about antecedent moisture content, storage capacity, and precipitation amount to identify thresholds that trigger fast or slow flowpaths. This dimensionless number serves as a first indicator to sort an event into a reaction class. In a second step the parameters that are known to govern hydrologic response within that class can help making hydrologic response prediction easier.