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Patterns of predictability in hydrological threshold systems

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Observations of hydrological response often exhibit considerable scatter that is difficult to interpret. In this paper, we examine runoff production of 53 sprinkling experiments on the water-repellent soils in the southern Alps of Switzerland; simulated plot scale tracer transport in the macroporous soils at the Weiherbach site, Germany; and runoff generation data from the 2.3 km^2 Tannhausen catchment, Germany, that has cracking soils. The response at the three sites is highly dependent on the initial soil moisture state as a result of the threshold dynamics of the systems. A simple statistical model of threshold behavior is proposed to help interpret the scatter in the observations. Specifically, the model portrays how the inherent macro state uncertainty of initial soil moisture translates into the scatter of the observed system response. The statistical model is then used to explore the asymptotic pattern of predictability when increasing the number of observations, which is normally not possible in a field study. Even though the physical and chemical mechanisms of the processes at the three sites are different, the predictability patterns are remarkably similar. Predictability is smallest when the system state is close to the threshold and increases as the system state moves away from it. There is inherent uncertainty in the response data that is not measurement error but is related to the observability of the initial conditions.