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Chaos theory as a bridge between deterministic and stochastic views for hydrologic modeling

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Two modeling approaches are prevalent in hydrology: deterministic and stochastic. The deterministic approach may be supported on the basis of the 'permanent' nature of the ocean-earth-atmosphere structure and the 'cyclical' nature of mechanisms that take place within it. The stochastic approach may be favored because of the 'highly irregular and complex nature' of hydrologic phenomena and our 'limited ability to observe' the detailed variations. With these two contrasting concepts, asking the question whether hydrologic phenomena are better modeled using a deterministic approach or a stochastic approach is meaningless. In fact, for most (if not all) hydrologic phenomena, both the deterministic approach and the stochastic approach are complementary to each other. This may be supported by our observation of both 'deterministic' and 'random' nature of hydrologic phenomena at 'one or more scales' in time and/or space; for instance, there exists a significant deterministic nature in river flow in the form of seasonality and annual cycle, whereas the interactions of the various mechanisms involved in the river flow phenomenon and their various degrees of nonlinearity bring randomness. It is reasonable, therefore, to argue that use of an integrated modeling approach that incorporates both the deterministic and the stochastic components will produce greater success compared to either a deterministic approach or a stochastic approach independently. This study discusses the role of chaos theory as a potential avenue to the formulation of an integrated deterministic-stochastic approach. Through presentation of its fundamental principles (nonlinear interdependence, hidden determinism and order, sensitivity to initial conditions) and their relevance in hydrologic systems, the study contends that chaos theory can serve as a bridge between the deterministic and stochastic 'extreme' views and offer a 'middle-ground' approach. Specific examples of chaos theory applications to a host of hydrologic systems are provided to further support this argument.