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Idle thoughts on a unifying theory of catchment hydrology

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The status of a theory is higher than that of a model. A hydrologic theory would have to apply to a range of climates, geological settings and a range of scales. One would expect that it has been so thoroughly tested and developed that we know there is indeed some range of phenomena for which it gives correct predictions every time. And it would always remain part of our understanding of hydrology. Currently, there exists no universal theory of catchment hydrology. There are different concepts for different parts of the hydrologic cycle and different spatial and temporal scales. The various branches of hydrology, however, do show remarkable parallels. The nature of hydrological variability is remarkably similar for different processes - organised variability at many scales - and the measurement techniques available to probe them have similar characteristics as well. In this paper, these common threads will be used in discussing concepts that may help shape a theory of catchment hydrology. Given the presence of variability at many scales, linking hydrological processes at different space and time scales is a possible starting point. In the time domain, event scale processes can be linked to the seasonal water balance and vice versa; seasonal processes to long term behaviour etc.. The important thing here would be to formulate processes simultaneously at various scales and then link them, rather than to upscale small scale processes all the way to obtain aggregate behaviour. The scale links will be controlled by the type of variability to be captured. There are often incompatibilities between the scales of processes and those of the measurements. Another starting point is hence to characterise measured variability by the space-time scales of processes relative to those of the measurements. The idea would be to focus on the order of magnitudes of the relative scales, e.g., storm size relative to catchment size. A new theory may involve an increased focus on interactions and feedbacks between different processes

such as those involving vegetation. Much of the exiting research in hydrology, currently, focuses on the interfaces between media, between macropores and the matrix in soils, streams and aquifers, the land and the atmosphere to name only a few. Connecting these domains may become instrumental in shaping a new theory. There is, however, a tendency for arriving at an exceedingly large complexity as one builds together candidate components of a model or a theory. The level of complexity of a theory will clearly be an important consideration. An elegant, parsimonious theory may be favoured over a more complex one provided it captures the essential complexity. Observed space-time patterns of hydrological variables are becoming available by novel measurement techniques and these may greatly assist in defining the structure of the essential processes to be dealt with. Detailed process knowledge has been obtained in numerous research catchments which is difficult to generalise to parts of the landscape where less detailed information is available. To address this generalisation issue, a theory may use comparative hydrology to develop a common method for assessing and quantifying hydrological similarity, through comparisons between catchments in different hydrologic regimes. The theory would have to be valid for all these regimes. More generally speaking, the level of detail with which one can measure hydrological variables along with the non-linearity of the system will set limits to the repeatability of experiments, the predictability of models, and the degree to which a theory will match observed behaviour. Among the key unresolved issues and research challenges in hydrology hence is separating the predictable and the unpredictable. A theory needs to focus on patterns of predictability.