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Simple models for complex hydrologic behavior: a challenge for basic research and engineering

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An old joke defines a ’scientist’ as someone who wants to understand a problem without solving it, and an ’engineer’ as someone who wants to solve a problem without understanding it. Hydrologists need to defy these stereotypes, both to advance the science of hydrology and to solve practical water resource problems. Effectively solving water resource problems will require better scientific understanding of hydrologic processes. Conversely, and perhaps less obviously, a deeper respect for the practical realities of real-world problems will help to advance the science of hydrology.

Recent progress in hydrologic science is challenging the intuitively appealing and computationally convenient models that have been the foundation for engineering approaches to streamflow forecasting and contaminant transport problems. For example, although catchments have often been conceptualized as linear reservoirs, it has become clear that the intrinsic nonlinearity of many hydrological processes is essential to understanding catchments’ rainfall-runoff behavior. Similarly, although subsurface transport and mixing in catchments has often been modeled by tank reactors with exponential residence time distributions, there is now clear evidence that typical residence time distributions in real-world catchments are markedly non-exponential. At smaller scales, contaminant transport has often been modeled by Gaussian plumes although field data clearly show that many contaminant plumes are dramatically non-Gaussian. The immediate challenge is to capture these kinds of real-world complexi-

ties in prediction and analysis tools that are still useful in an operational context.

For scientific reasons as well as practical ones, hydrology needs new conceptual models that make the complex realities of hydrological systems understandable and analytically tractable. In attempting to embrace the full complexity of hydrological systems, many hydrological models have not only become too complex for operational use; they have become too complex to be understood, too highly parameterized to be rigorously tested, and too data-hungry to be widely applied.

These considerations point to the need to develop new models which find a ’middle path’ between the conceptually simple linear models often used in engineering approaches, and the complex spatially distributed models often used in research hydrology. The goal of such ’gray box’ models is to capture the aggregate behavior of complex hydrologic systems directly in their governing equations, so that complex model structures and elaborate mathematical schemes are not required. Examples of recent efforts toward this goal will be presented.