A manifesto for the equifinality thesis

This essay discusses some of the issues involved in the identification and predictions of hydrological models given some calibration data. The reasons for the incompleteness of traditional calibration methods are discussed. The argument is made that the potential for multiple acceptable models as representations of hydrological and other environmental systems (the equifinality thesis) should be given more serious consideration than hitherto. It proposes some techniques for an extended GLUE methodology to make it more rigorous and outlines some of the research issues still to be resolved. © 2005 Elsevier Ltd All rights reserved.

Evidence for intensification of the global water cycle: Review and synthesis

One of the more important questions in hydrology is: if the climate warms in the future, will there be an intensification of the water cycle and, if so, the nature of that intensification? There is considerable interest in this question because an intensification of the water cycle may lead to changes in water-resource availability, an increase in the frequency and intensity of tropical storms, floods, and droughts, and an amplification of warming through the water vapor feedback. Empirical evidence for ongoing intensification of the water cycle would provide additional support for the theoretical framework that links intensification with warming. This paper briefly reviews the current state of science regarding historical trends in hydrologic variables, including precipitation, runoff, tropospheric water vapor, soil moisture, glacier mass balance, evaporation, evapotranspiration, and growing season length. Data are often incomplete in spatial and temporal domains and regional analyses are variable and sometimes contradictory; however, the weight of evidence indicates an ongoing intensification of the water cycle. In contrast to these trends, the empirical evidence to date does not consistently support an increase in the frequency or intensity of tropical storms and floods. © 2005 Elsevier Ltd All rights reserved.

A global sensitivity analysis tool for the parameters of multi-variable catchment models

Over-parameterisation is a well-known and often described problem in hydrological models, especially for distributed models. Therefore, methods to reduce the number of parameters by sensitivity analysis are important for the efficient use of these models. This paper describes a novel sampling strategy that is a combination of latin-hypercube and one-factor-at-a-time sampling that allows a global sensitivity analysis for a long list of parameters with only a limited number of model runs. The method is illustrated with an application of the water flow and water quality parameters of the distributed water quality program SWAT, considering flow, suspended sediment, total nitrogen, total phosphorus, nitrate and ammonia outputs at several locations in the Upper North Bosque River catchment in Texas and the Sandusky River catchment in Ohio. The application indicates that the methodology works successfully. The results also show that hydrologic parameters are dominant in controlling water quality predictions. Finally, the sensitivity results are not transferable between basins and thus the analysis needs to be conducted separately for each study catchment. © 2005 Elsevier B.V. All rights reserved.

A review and evaluation of catchment transit time modeling

Transit time is a fundamental catchment descriptor that reveals information about storage, flow pathways and source of water in a single characteristic. Given the importance of transit time, little guidance exists for the application of transit time modeling in complex catchment systems. This paper presents an evaluation and review of the transit time literature in the context of catchments and water transit time estimation. It is motivated by new and emerging interests in transit time estimation in catchment hydrology and the need to distinguish approaches and assumptions in groundwater applications from catchment applications. The review is focused on lumped parameter transit time modeling for water draining catchments and provides a critical analysis of unresolved issues when applied at the catchment-scale. These issues include: (1) input characterization, (2) recharge estimation, (3) data record length problems, (4) stream sampling issues, (5) selection of transit time distributions, and (6) model evaluation. The intent is to promote new advances in catchment hydrology by clarifying and formalizing the assumptions, limitations, and methodologies in applying transit time models to catchments. © 2006 Elsevier B.V. All rights reserved.

Hydrological forecasting uncertainty assessment: Incoherence of the GLUE methodology

The aim of the paper is to demonstrate the incoherence, in terms of Bayesian inference, of the generalized likelihood uncertainty estimation (GLUE) approach, introduced by Beven and Binley in 1992. This results into a reduced capacity of the technique to extract information, in other words to "learn", from observations. The paper also discusses the implications of this reduced learning capacity for parameter estimation and hydrological forecasting uncertainty assessment, which has led to the definition of the "equifinality" principle. The notions of coherence for learning and prediction processes as well as the value of a statistical experiment are introduced. These concepts are useful in showing that the GLUE methodology...
Particle swarm optimization training algorithm for ANNs in stage prediction of Shing Mun River

An accurate water stage prediction allows the pertinent authority to issue a forewarning of the impending flood and to implement early evacuation measures when required. Existing methods including rainfall-runoff modeling or statistical techniques entail exogenous input together with a number of assumptions. The use of artificial neural networks (ANN) has been shown to be a cost-effective technique. But their training, usually with back-propagation algorithm or other gradient algorithms, is featured with certain drawbacks such as very slow convergence and easy entrapment in a local minimum. In this paper, a particle swarm optimization model is adopted to train perceptrons. The approach is applied to predict water levels in Shing Mun River of Hong Kong with different lead times on the basis of the upstream gauging stations or stage/time history at the specific station. It is shown that the PSO technique can act as an alternative training algorithm for ANNs. © 2006 Elsevier B.V. All rights reserved.

Analysis of spatial distribution and temporal trend of reference evapotranspiration and pan evaporation in Changjiang (Yangtze River) catchment

In this study the Penman-Monteith reference evapotranspiration, pan evaporation measured by a 20 cm pan, and pan coefficient, i.e., the ratio of Penman-Monteith evapotranspiration to pan evaporation, at 150 meteorological stations during 1960-2000 in the Changjiang (Yangtze River) catchment in China are calculated, compared and regionally mapped. Their spatial distributions and temporal variations are examined and the causes for the variations are discussed. The spatial distributions of temporal trends in the reference evapotranspiration as well as in the meteorological variables that determine evapotranspiration are analyzed. The contributions of various meteorological variables to the temporal trend detected in the reference evapotranspiration and pan evaporation are then determined. The results show that: (1) the spatial distributions of reference evapotranspiration and pan evaporation are roughly similar. Spatial correlation coefficients between the reference evapotranspiration and the pan evaporation are high for both the seasonal and annual values. The temporal correlation between the two estimates is higher in the lower (humid) region than in the upper (dry) region. The spatial distribution pattern of the pan coefficient is significantly influenced by wind speed and relative humidity in the region. Higher values of the pan coefficient were found in the central area of the catchment with a relatively high humidity (as compared with the upper area) and a very low wind speed (as compared with other areas); (2) for the whole catchment, there is a significant decreasing trend in both the reference evapotranspiration and pan evaporation, which is mainly caused by a significant decrease in the net total radiation and to a lesser extent by a significant decrease in the wind speed over the catchment. No temporal trend is detected for the pan coefficient; (3) sensitivity analysis shows that the reference evapotranspiration is most sensitive to the net total radiation, followed by relative humidity, air temperature and wind speed. © 2005 Elsevier B.V. All rights reserved.

Effects of differing wildfire severities on soil wettability and implications for hydrological response

Fire-induced or enhanced soil water repellency is often viewed as a key cause of the substantial increases in runoff and erosion following severe wildfires. In two studies, the effects of different fire severities on soil water repellency were examined in eucalypt forest catchments in the Sandstone Tablelands near Sydney, burnt in 2001 and 2003. At sites affected by different fire severities and in long-unburnt control sites, repellency persistence was determined in situ and in the laboratory for surface and subsurface soil samples (n=846) using the Water Drop Penetration Time (WDPT) test. All long-unburnt samples were found to be water repellent, with severe to extreme persistence (>900 s) being dominant for surface (0-2.5 cm) and slight to moderate persistence (10-900 s) for subsurface (2.5-5 cm) soil, indicating naturally very high 'background' levels of repellency. In contrast to the generation or enhancement of repellency usually reported following forest fires of similar severity in previous studies, burning caused widespread destruction of repellency. The mineral soil depth to which repellency was destroyed (0.5-5 cm) was found to increase with burn severity. Below this charred wattle layer, persistence of pre-existing water repellency increased. Two years after the fire, the frequency of extreme repellency persistence was reduced in the surface and subsurface. However, recovery to pre-fire repellency levels had not been achieved. The associated hydrological impacts of these fire effects are more complex than simply the enhancement of overland flow, runoff and soil erosion with increasing fire severity. For forest fires sufficiently severe to remove foliage and ground litter above already repellent soil, a more severe burn, in which there is destruction of surface soil repellency, would result in lower runoff response compared to a burn insufficiently severe to destroy surface repellency. During storms intense enough to saturate the wattleable surface rapidly, this layer may, however, be removed by overland flow, with potentially severe implications for soil fertility and seedbed survival, post-fire ecosystem recovery, and downstream sedimentation and water quality. The results demonstrate that existing fire severity classifications are not well suited to predicting fire impacts on soil hydrological responses and highlight the need for a new fire severity evaluation scheme. A scheme encompassing not only foliage and ground cover status, but also changes to surface and subsurface soil hydrological properties, would