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REW approach, a new blueprint for distributed hydrological modeling at the catchment scale: application to a mesoscale catchment

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Reggiani *et al.* (1998, 1999) developed a new unifying theoretical framework for the analysis of hydrological responses at the catchment scale by deriving, from first principles and in a most general manner, the balance equations for mass, momentum, energy and entropy, for well defined spatial domains, which they called the Representative Elementary Watershed (REW). With the 2^{nd} law of thermodynamics as a guide they followed these up with the development of a general constitutive theory to assist in the parameterizations of the exchange fluxes of mass, momentum and energy between different REWs and between different sub-regions of each REW. The resulting set of mass, momentum and energy balance equations, combined with geometrical relationships, constitute a determinate system of coupled, nonlinear ordinary differential equations and algebraic equations in REW-scale state variables (storages of water and velocities). This formulation attempts to parameterize all variability at scales below the REW, and explicitly resolves variability at scales larger than the REW scale. The effects of sub-REW variability of climate, soils, topography and vegetation are deemed to express themselves through exchange coefficients that appear in the closure relations chosen to parameterize the various mass and momentum fluxes. The REW approach, through the new balance equations so derived, has been suggested as the blueprint for a new generation of distributed models, since it has the potential to overcome many shortcomings of, and difficulties with, the current generation of distributed models that are based on REV-scale theories. However, considerable effort is still required to turn these new balance equations, derived in a general manner, into a numerical model capable of predicting the hydrological behavior of actual catchments,

both gauged and ungauged. The main components of the new model blueprint are: 1) procedures for the development of physically reasonable closure relations for mass and momentum exchange fluxes that parameterize the effects of sub-REW variability, 2) appropriate numerical schemes to efficiently solve the resulting set of coupled, non-linear ordinary differential equations and algebraic equations, 3) methodologies for the estimation of model parameters, 4) approaches to verify the physical reasonableness of the model for application in real catchments, and to validate model parameterizations using observed data, and 5) methods to assess the reliability of the model through systematic analysis of predictive uncertainty. The aims of this paper are to present a detailed overview of these building blocks of the new model blueprint, summarize the progress that has been made, outline the work that is still required. The paper concludes with an example application (calibration and subsequent validation) of an early version of the REW scale distributed numerical model to a meso-scale catchment in the south-west of Western Australia, and will argue that the REW approach constitutes a new model blueprint that could be adopted to advance our capability to make hydrological predictions in ungauged basins.