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Development of closure relations and process paramaterizations with respect to the REW approach: recent progress and future prospects

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Reggiani *et al.* (1998, 1999) recently derived, from first principles and in a general manner, the balance equations for mass, momentum and energy at what they called the Representative Elementary Watershed (or REW) scale. However, the mass balance equations of the REW approach include mass exchange flux terms which must be defined externally before their application to real catchments. Developing physically reasonable "closure relations" for these mass exchange flux terms is a crucial pre-requisite for the success of the REW approach. As a guidance to the development of closure relations expressing mass exchange fluxes as functions of relevant state variables in a physically reasonable way, and in the process effectively parameterizing the effects of sub-grid or sub-REW heterogeneity of catchment physiographic properties on these mass exchange fluxes, this paper considers four different approaches, namely the field experimental approach, a theoretical/analytical approach, a numerical approach, and a hybrid approach combining one or more of the above. Based on the concept of the scaleway (Vogel and Roth, 2003) and the disaggregation-aggregation approach (Viney and Sivapalan, 2004), and using the data set from Weiherbach catchment in Germany, closure relations for infiltration, exfiltration and groundwater recharge, seepage outflow, concentrated overland flow and saturated overland flow. The detailed model, CATFLOW, was also used to derive REW scale pressure-saturation (i.e., water retention curve) and hydraulic conductivity-saturation relationships for the unsaturated zone. In addition to these, to complete the specification of the REW scale balance equations, a relationship for the saturated area fraction as a func-

tion of saturated zone depth was derived for an assumed topography on the basis of TOPMODEL assumptions. The resulting numerical watershed model, CREW, is then used to carry out sensitivity analyses with respect to various combinations of climate, soil, vegetation and topographies, in order to test the reasonableness of the derived closure relations in the context of the complete catchment response. We also assess the applicabilities of the parameter values extracted from the upscaling procedure in terms of their ability to reproduce observed hydrographs within the CREW modeling framework. The paper will present these results and a philosophical discussion of opportunities for the improvement of the developed closure relations through further testing, focused field measurements, functional associations.