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Hydrological Simulation of River Basins at Different Spatial Scales: 1. Generalization and Averaging Algorithms

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Abstract—ECOlogical Model for Applied Geophysics have been used as a sample to develop algorithms for generalizing the description and parameters of moisture exchange in physically based runoff formation models when the spatial scale of the model is changed; the algorithms are based on the use of statistical distributions and various procedures of spatial averaging of land surface parameters depending on the algorithms used to calculate individual hydrological processes. The proposed algorithms make it possible to give a physical interpretation of some aggregated effective parameters of conceptual lumped-parameter hydrological models and, in some cases, to evaluate the errors caused by the spatial averaging of heterogeneities in land surface characteristics.

Keywords: river basin, runoff formation, simulation, scaling, generalization algorithms, parameter averaging

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A rapid development and introduction of physically based models describing runoff formation took place in the 1980s [7, 9, 12]; however, as soon as the 1990s, the enthusiasm caused by the achievements in the description and simulation of individual processes of the hydrological cycle declined appreciably, and the problems of physically based simulation of river basins have been the topic of active discussions in the hydrological community in the recent 20 years. The most illustrious critics of this line in the simulation are K. Beven [13, 14, 23] and Yu.B. and T.A. Vinogradov [1, 2]. The main declared faults of the physically based models are that the equations of mathematical physics inadequately describe some hydrological processes and are applied to improper spatial scales on real watersheds, where model parameters cannot be measured, so the model required calibrations as is common in conceptual runoff models. The active discussion between the supporters and critics of the conventional physicomathematical line in the simulation of runoff formation is not aimed to belittle the scientific potential of such models, and the achievements in this field are recognized by the majority of leading hydrologists. The objective of the discussion is to search the way to solving the problem of scaling in the simulation of hydrological processes in the passage from a point to a slope and further to an elementary watershed and river basin, and, finally, to improve the current generation of physically based model of runoff formation. In [3, 8], the reserves for such improvement are associated with more specific description of individual hydrological processes with incorporation in the models of new mechanisms and statistical regularities of spatial variations of watershed characteristics. The critics of this approach [1, 2, 13, 14, 23] consider the potential for the development of the models to be not the improvement of the theory of description of individual processes, but the focus on the spatial information and process parameterization at the spatial scale typical of the scale of river basin simulation; at the same time, they admit a variant of model conceptualization.

In the opinion of some hydrologists, the characteristic scale of river basins in the use of conventional physically based runoff formation models is limited to the size of a small (elementary) river basin. Within such basin, the models of this type can be used to reproduce hydrological processes on different parts of slopes (a characteristic scale of a model cell is hundreds of square meters) and in channel network with great detail. In the hydrological simulation of large areas and river systems, larger model cells are to be used with a size of the order of tens, hundreds, or even thousands square kilometers. In this case, the problem of scaling in hydrological models requires additional theoretical substantiation. The problem is to find new (compared with a point) simulation units of a certain scale, to generalize (filter) small-scale fluctuations of characteristics that are of secondary significance at this scale, to parameterize the models of hydrological processes at the meso- or macroscale level, and to find effective model parameters.

An important step in solving the problem of scale is the concept of representative elementary area (REA)