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How to adapt a nonurban model structure to account for urbanization?

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A catchment-scale hydrological model encompasses a set of hypotheses that are capable of describing, in a lumped way, the water movement in a hydrological catchment. As the catchment undergoes a heavy urbanization gradient, the catchment's hydrological behavior changes. A new set of hypotheses is then needed to consider the presence of urban-introduced features in the hydrological cycle. Our objective is to reach a parsimonious model structure that is capable of sufficiently reproducing the rainfall-runoff relationship along a wide range of urbanization levels, including the non-urbanized situation. Given a model that is adequate for non-urbanized catchments, what modifications should one operate on the initial model hypotheses to account for (1) the presence of impervious surfaces within the catchment and (2) the interactions between the pervious and the newly added impervious surfaces? To this aim, a large sample of 268 American and French urbanized catchments was prepared. We have chosen an initial hydrological model, GR4H, whose structure has been tested and improved using large international samples of catchments, but predominately non-urbanized. Analyzing the hydrological behavior of the urbanized catchments has helped us in formulating a set of modifications to be made on the initial model structure. Step by step, the relevance of each modification was assessed using 10 continuous, frequency- and event-based evaluation criteria. As a result, the model performances were significantly improved when (a) the net rainfall production was considered to be controlled not only by the antecedent soil moisture conditions but also by the catchment's mean imperviousness, mainly during low-intensity rainfall events, and (b) the fast flow branch was more privileged in routing, seeing that the response of the urbanized catchments was faster and highly reactive in comparison with the rural ones'. Unlike the initial model structure, the resulting one can help quantifying the impact of future urbanization schemes on the catchment's hydrological behavior.