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Which spatial discretization for distributed hydrological models?

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Distributed hydrological models are valuable tools to derive distributed estimation of the water balance components or study the impact of land-use change on water resources or water quality. In order to address these questions, the choice of an appropriate spatial resolution for the model is a crucial issue. The definition of the appropriate spatial scale must take into account various factors, sometimes contradictory i) what is the objective of the distributed hydrological modeling? What are the output variables and at which scale are they wished? ii) What is the resolution of the available input data (landscape descriptors but also model inputs such as rainfall)? iii) What are the active/dominant hydrological processes and what is their functional scale? iv) Which degree of heterogeneity is acceptable within the modeling units?

Once the objectives of the modeling exercise are clearly stated, the first step of the analysis is the definition of the modeled hydrological processes and of their landscape descriptors. Let's take an illustrative example and assume that the objective of the modeling exercise is to determine the components of the water balance on a catchment of about 10 000 km^2 at the annual, monthly and daily time scale. These components are simulated for the whole catchment, but also within sub-catchments. We also consider their evolution in a context of land-use change. The outputs of the models are therefore distributed values of rainfall, runoff, streamflow, groundwater recharge, evapotranspiration and soil water storage. The modeling units must therefore take into account the spatial resolution of climate input data, the limits of the groundwater systems, the river network and the slope due to its influence on lateral water redistribution. Furthermore if land use change is considered, its effect on evapotranspiration via a change in vegetation must be taken into account. The modeling units must therefore explicitly represent the various land-use. Once the appropriate

information layers have been defined, there is still the need to choose the proper scale of discretization and derive the “homogeneous” modeling units.

For this purpose, we propose a methodology based on landscape classification. As illustrated above, the modeler defines the set of natural factors/maps that characterize the spatial organization of water dynamics within the watershed, which are taken into account in the analysis. The superposition of such layers/maps using GIS gives a composed picture of the landscape, where the various classes are defined by a unique combination of the factors. The second step is the classification of this image using landscape classification techniques. A neighborhood window (size and shape) is chosen for the analysis. A set of reference zones in the landscape is defined according to the objectives, the catchment knowledge or a statistical analysis of available data. These references zone are characterized by their neighborhood composition, for instance using histograms of the initial classes. Then, the neighborhood histogram of each spatial point is calculated and the point is affected to a reference class, by minimizing the distance between its neighborhood composition (histogram) and that of the reference zones. The method avoids smoothing of the map by suppressing the smallest units (the role of which can be hydrologically very important) and provides a confidence map (the distance map) in the classification. The size of the neighborhood conditions the resolution of the final units but the modeler is able to add new reference zones is required and complexify/simplify the definition of the landscape, according to its objectives. However the final discretization must remain consistent with the resolution of input data (it is probably useless to have very fine units with a very crude rainfall description) and that of the source maps (slope, land-use, soil description). The methodology is illustrated for the upper Saône catchment (11700 km^2) in France.