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Towards a comprehensive physically-based rainfall-runoff model

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Abstract. This paper introduces TOPKAPI (TOPographic Kinematic APproximation and Integration), a new physically-based distributed rainfall-runoff model deriving from the integration in space of the kinematic wave model. The TOPKAPI approach transforms the rainfall-runoff and runoff routing processes into three 'structurally-similar' non-linear reservoir differential equations describing different hydrological and hydraulic processes. The geometry of the catchment is described by a lattice of cells over which the equations are integrated to lead to a cascade of non-linear reservoirs. The parameter values of the TOPKAPI model are shown to be scale independent and obtainable from digital elevation maps, soil maps and vegetation or land use maps in terms of slope, soil permeability, roughness and topology. It can be shown, under simplifying assumptions, that the non-linear reservoirs aggregate into three reservoir cascades at the basin scale representing the soil, the surface and the drainage network, following the topographic and geomorphologic elements of the catchment, with parameter values which can be estimated directly from the small scale ones. The main advantage of this approach lies in its capability of being applied at increasing spatial scales without losing model and parameter physical interpretation. The model is foreseen to be suitable for land-use and climate change impact assessment; for extreme flood analysis, given the possibility of its extension to ungauged catchments; and last but not least as a promising tool for use with General Circulation Models (GCMs). To demonstrate the quality of the comprehensive distributed/lumped TOPKAPI approach, this paper presents a case study application to the Upper Reno river basin with an area of 1051 km^2 based on a DEM grid scale of 200 m. In addition, a real-world case of applying the TOPKAPI model to the Arno river basin, with an area of 8135 km^2 and using a DEM grid scale of 1000 m, for the development of the real-time flood forecasting system of the Arno river will be described. The TOPKAPI model results demonstrate good agreement between observed and simulated responses in the two catchments, which encourages further developments of the model.

Keywords: rainfall-runoff modelling, topographic, kinematic wave approximation, spatial integration, physical meaning, non-linear reservoir model, distributed and lumped

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