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An Integrated Lowland Catchment Model for the Upper Narew

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The aim of this work is the development of an integrated Data Based Mechanistic (DBM) rainfall-flow and flow-routing model suitable for scenario analysis of the Upper River Narew catchment in northeast Poland. This area encloses valuable wetland ecosystems of the Narew National Park (NPN). The available data include daily rainfall observations, temperature measurements and water level measurements at 7 gauging stations situated along the river reach and its tributaries (Bondary, Narewka, Narew, Ploski, Chraboły, Suraż and Żółtki). The modelling tool developed is formulated in MATLAB-SIMULINK language. It has a flexible, modular structure that can easily be extended by adding new features, such as a snow-melt module or a distributed routing module. The basic system structure includes rainfall-flow and flow routing modules, based on a Stochastic Transfer Function (STF) approach combined with nonlinear transformation of rainfall into effective rainfall.
Most of the identified routing models have first-order dynamics. The best results were obtained for the neighbouring sub-reaches and there was no significant improvement of model performance if separate parallel inputs were used instead of an average sum. This result indicates that inflows from tributaries are highly cross-correlated. Moreover, there are many tributaries unaccounted for along the river, which change our perception of the flow dynamics at the downstream reach. Therefore, even though the flood peak travels in about 4-5 days from upstream to downstream (Bondary to Żółtki), the maximum advective delay obtained for the Suraż model with averaged flows from Bondary, Narewka and Orlanka on the input equals only 1 day. This model and the similar MISO model using parallel inputs are the only models suitable for flood forecasting. Models obtained without advective delay may be useful for scenario analysis. The STF models derived to describe the rainfall-flow processes in the sub-catchments of Narewka and Chraboły apply the exponential transformation of rainfall with flow measurements used as the surrogate of soil moisture content. This approach is suitable for a "what-if" scenario analysis of water management policy down the river Narew, but it is not suitable for off-line model simulations. Therefore, the Soil Moisture Accounting (SMA) technique was used to obtain the effective rainfall transformation, used in the STF model as an input variable. The derived STF modules describing rainfall-flow and flow routing in the Narew catchment were combined into an integrated rainfall-flow/level routing system. The system is subsequently used to build a SIMULINK model of the entire Upper Narew catchment, for the purpose of scenario analysis. That model can be also used for the testing and derivation of optimal reservoir releases for the purpose of drought and flood mitigation.
Another application is in online data assimilation and forecasting. In the case study considered here, forecasts of temperature and precipitation are obtained from the European Centre for Medium–Range Weather Forecasts (ECMWF). We test the responses of the STF model of the Narew catchment to the ECMWF precipitation and temperature forecasts for a range of forecast lead-times (1-6 days).