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Modelling Hydrological Processes in Presence of Uncertain or Unreliable Forcing Data and Land Surface Parameters

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Construction of a model for simulating hydrological processes, to our opinion, should be based on mathematical description of the real physical heat and water exchange processes occurring in a soil – vegetation/snow cover – atmosphere system rather than on available data. This allows one to create more universal model, which can be applied at different temporal and spatial scales and under different natural conditions. More than that, such a model can be applied for poorly-gauged basins and in the presence of uncertain/unreliable forcing data and land surface parameters, provided that reliable runoff measurements are available at least for several years. The latter is necessary for model calibration to reduce the impact of uncertainties in input data on model results. The present work is intended to confirm the above statements using the land surface model SWAP (Soil Water – Atmosphere – Plants).

SWAP is a physically-based model describing the processes of heat and water exchange within a soil–vegetation/snow cover–atmosphere system (SVAS). The model can be applied both for point (or grid cell) simulations of vertical fluxes and state variables of SVAS in atmospheric science applications, and for simulating streamflow on different scales — from small catchments to continental scale river basins. The results of model validations have demonstrated that SWAP is able to reproduce (without calibration) heat and water exchange processes (in particular, hydrological processes) adequately, provided that input data of high quality are available. In poorly-gauged basins, alternative sources of information should be used. Here, the global data sets on forcing data and land surface parameters were used for simulating streamflow from two pan-Arctic river basins (the Mezen and the Pechora basins with an area of 78 000 and 324 000 sq.km, respectively), located in the northeast part of the European Russia. The Mezen and the Pechora basins were represented for modeling purposes by, respectively, 13 and 60 one-degree grid cells connected by river networks. Runoff was modeled for each cell and then transformed by a river routing model to simulate streamflow at a river basin outlet. The land surface parameters for each grid cell were taken from the one-degree global data sets of the Second Global Soil Wetness Project (GSWP-2). Seven soil and vegetation parameters were selected for calibration. Meteorological forcing data were taken from the GSWP-2 3-hour global data sets for the period of 1983-1995. To reduce the systematic errors in precipitation and incoming radiation adjustment factors were applied separately for liquid and solid precipitation, as well as for incoming shortwave and longwave radiation. Their values can be obtained by calibration. Thus there were 11 calibrated parameters. Calibration was performed by means of stochastic optimization technique using daily streamflow measured during 1986-1990 at the Malonisogorskaya gauging station for the Mezen River and at the Oksino gauging station for the Pechora River. Model validation using optimal values of the calibrated parameters was performed for the next 5 years. The Nash and Sutcliffe efficiency of daily runoff simulation for the validation period (for both rivers) was within the range 0.75-0.82, the correlation coefficient equaled to 0.88-0.91, the bias did not exceed 6%. Thus it can be concluded, that the physically–based LSM SWAP can be used as a quite functional tool for hydrological modelling in the case of poor, uncertain and unreliable input data.