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Climate change impact on streamflow in large-scale river basins: projections and their uncertainties sourced from GCMs and RCP scenarios

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Climate change impact on river runoff was investigated using a physically-based Land Surface Model SWAP developed in the Institute of Water Problems of the Russian Academy of Sciences. Twelve large-scale river basins suggested within the framework of the ISI-MIP project were used in this study. For simulating runoff at the river basin outlets, schematization of each basin as a set of 0.5°x0.5° computational grid cells connected by a river network was carried out. Model parameters for each grid cell were taken or derived from the ECOCLIMAP data set after its aggregation for 0.5 degree grid cells. Soil parameters were derived from the values of Clay and Sand given in ECOCLIMAP. Meteorological forcing data (including precipitation, air temperature, shortwave and longwave downward radiation, air humidity, wind speed, and air pressure) for historical period (1969-2001) needed for model calibration and validation were taken from the WATCH data set with one-day time step.
Simulations of river runoff for the historical period performed by SWAP with a priori input data showed a poor agreement with observations. Calibration of a number of model parameters against measured monthly river runoff using SCE-UA optimization algorithm resulted in substantial improvement of model performance with respect to goodness-of-fit statistics and the shape of hydrograph.
Climate change impact on river runoff was studied using meteorological projections (for 2005-2100) from five General Circulation Models (GCMs) (including GFDL-ESM2M, HadGEM2-ES, IPSL-CM5A-LR, MIROC-ESM-CHEM, and NorESM1-M) under four RCP scenarios (RCP2.6, RCP4.5, RCP6.0, and RCP8.5). All GCMs' projections were bias-corrected to WATCH within the framework of the ISI-MIP. First of all, we performed historical simulations of streamflow for 12 river basins using the SWAP model and meteorological outputs from the five GCMs. Satisfactory agreement between simulated and observed mean monthly runoff was obtained for 11 river basins.
Then, for each of these basins, 20 projections (5 models x 4 scenarios) of possible changes in river runoff during the 21st century were simulated by SWAP. According to the obtained projections, for some rivers (the Amazon, Rhine, Mississippi, Mackenzie, Lena and Ganges), runoff will increase by the end of the 21st century by 1.4 - 22%, for the other three rivers (the Niger, Tagus and Darling) runoff will decrease by 4 - 48%, while for the Yellow and Yangtze rivers there will be no changes in runoff.
Analysis of the obtained hydrological projections allowed us to estimate their uncertainties resulted from application of various GCMs and different RCP scenarios. It was found that the uncertainties increase by the end of the 21st century. The largest uncertainties were obtained for the Darling and Tagus rivers. On the average, the contribution of different scenarios into the uncertainty of river runoff is larger (nearly twice in 2006-2067 and 1.5 times in 2068-2099) than the contribution of different GCMs.