Possible impacts of climate change on runoff characteristics of rivers in Hesse based on the ECHAM4/B2 projection

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Research methodology

A study of 9 catchments in Hesse with catchment sizes varying between 1200 km² and 5300 km² was carried out to quantify the possible impacts of climate change on the hydrological behaviour. Climate data based on the general circulation model ECHAM4-OPYC3 were downscaled by the statistical downscaling method WETTREG (ENKE, 2003) in order to generate daily point values corresponding to meteorological stations of Germany's national meteorological service (Deutscher Wetterdienst). These data were used to force the conceptual water balance model LARSIM (LUDWIG and BREMICKER, 2006) to simulate the present (1981-2000) and future (2011-2050) streamflow for catchments in Hesse.

For the period 2011-2050 the IPCC emission scenario B2 was applied. LARSIM allows a process-based and spatially distributed simulation of the medium-scale mainland water cycle. The model was validated comparing measured streamflow with streamflow resulting from a simulation with observed hydrometeorological data. Climate change impacts were related to the differences between simulated streamflow driven by the WETTREG data for the reference period 1981-2000 and streamflow driven by WETTREG data for the period 2011-2050 based on the emission scenario B2. Each simulation consists of ten statistical realisations with a time series of 20 years per decade. In the following, mean monthly values of mean discharge, low flow and annual floods were calculated and compared.

Results

Annual precipitation amounts increase only slightly, whereas a clear disproportion towards increasing precipitation (+ 8 %) during the hydrological winter half-year (i.e. November – April) and a corresponding decrease during the hydrological summer half-year (–8 %) have been observed. Rising mean annual temperatures of between + 1.2 K and + 1.8 K in the decades from 2011 to 2050 compared to the reference period indicate also a decreasing influence of snow cover on hydrological processes.

In general a clear intensification of the existing hydrological regime with winterly high streamflow and summerly low flows can be expected. The changes in peak flow are quite unsure, extreme values for regional precipitation from the meteorological model as well as some other points in the whole modelling chain are responsible for this point.

Concerning the extent of changes in the hydrological behaviour, two regions in Hesse can be separated:

- Rivers in the southern and central part of Hesse show increasing discharge values. In the winter half-year discharge increases between 10 and 18 %, whereas a decrease by about 15 % occurs during the summer half-year. Also statistical low-flow values decrease in this order of magnitude. Storm runoff values show bigger variations with an increase up to 30 % in the mean monthly storm runoff from December to February, about 15 % in mean yearly floods and about 20 % for extreme floods.

- The catchments in the north/northeast of Hesse show for all mean and low-flow values decreasing values with –15 to –20 % for the mean yearly discharge, –25 to –50 % for the summer half-year and about –10 % for the winter half-year. Extreme floods increase only slightly (+ 5%) in this region with relatively drier conditions compared to the other regions in Hesse.

The combination of one global meteorological model with one emission scenario results in a possible projection of the future behaviour of rivers in Hesse. It is clear that more combinations of meteorological models and emission scenarios have to be examined to get quality-based results for implementations of climate change adaptions in hydrological practice.

Literature:

ENKE, W. (2003): Anwendung eines statistischen Regionalisierungsmodells auf das Szenario B2 des ECHAM4 OPYC3 Klima-Simulationslaufes bis 2050 zur Abschätzung regionaler Klimaänderungen für das Bundesland Hessen. Abschlussbericht, Stahnsdorf.

LUDWIG, K. and M. BREMICKER (2006): The Water Balance Model LARSIM – Design, Content and Applications. Freiburger Schriften zur Hydrologie, Universität Freiburg i.Br., 2006.