SCHOOL OF DOCTORAL STUDIES IN ENVIRONMENTAL ENGINEERING

Department of Civil and Environmental Engineering
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XXII cycle

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On the effects of hydrological uncertainty in assessing the impacts of climate change on water resources

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Abstract

This dissertation focuses on the assessment of projected changes on water resources by the end of this century (2071-2100), considering an ensemble of high resolution future climate scenarios, the effects of hydrological parameterisation, and the bias of the hydrological model in representing different streamflow magnitudes.

Quantification of the impacts of climate change on water resources will depend on the emission scenario, climate model, downscaling technique and impact model used to drive the impact study. In particular, hydrological impact studies involve important decisions (e.g., model structure, parameterisation, input data) whose effects are reflected into the final impacts. As a result, quantification of impacts of climate change have to be seen as a ”of uncertainty”, in which decisions taken in every step of the assessment process convey uncertainties that are unavoidably propagated to subsequent levels. At the other hand, uncertainties in projections of climate models and those involved in the quantification of their hydrological response limit the understanding of those future impacts and hamper the assessment of mitigation policies.

The Soil and Water Assessment Tool (SWAT) hydrological model was set up for daily simulations of the western part of the Ebro River Basin (42000 km^2) in Spain, during the control period 01/Jan/1961 to 31/Dec/1990, and two subcatchments were selected for testing the methodology proposed in this dissertation. A sensitivity analysis with Latin Hypercube One-factor-At-a-Time (LH-OAT) was carried out in order to identify parameters with a high effect on simulated streamflows. Then, an uncertainty analysis was carried out using the Generalized Likelihood Uncertainty Estimation (GLUE) methodology, in order to select parameter sets that can be considered as acceptable simulators of the system, adopting a re-scaled Nash-Sutcliffe as ”less-formal” likelihood, and a cut-off threshold equal to zero to discriminate between behavioural and non-behavioural simulators. Afterwards, a Latin Hypercube (LH) sampling strategy was implemented within GLUE, in order to reduce the number of model runs required to obtain a good exploration of the parameter space. The 95% of the cumulative distribution of each predicted output, weighted by the re-scaled likelihood of each behavioural parameter set, was used to compute the predictive uncertainties bounds, during the control and future scenarios.

Bias-corrected daily time series of precipitation and air temperature, for the future period 2071-2100, were derived from an ensemble of six high-resolution climate change scenarios, selected from the EU FP5 PRUDENCE project. Long-term averages of precipitation and temperature fields were computed for the control period, and projected anomalies for the future scenarios were computed as well, in an annual, seasonal and monthly basis, including expected changes for different elevation bands within the basin. The same bias-corrected time series were then used to drive daily hydrological simulations during the future period on the two selected catchments. For each climate scenario, a number of simulations equal to the number of behavioural parameter sets obtained during the uncertainty analysis was carried out. Resulting streamflows were used to compute daily flow duration curves (FDCs) to provide a qualitative assessment of the relative importance of uncertainties coming from the choice of the driving RCM and from hydrological parameterisation. In addition, streamflows derived from running each climate scenario with its corresponding behavioural parameter sets, were used to compute empirical cumulative density functions (ECDFs) of three selected percentiles, representing different flow magnitudes, in order to provide a quantitative assessment of the projected changes in streamflows.

We observed that the hydrological parametric uncertainty was larger than the uncertainty coming from the driving RCM, during the complete future period and each one of the four seasons, for the two selected catchments. However, this result can not be generalised, because it is conditional to decisions taken during the uncertainty analysis and to the ensemble of RCMs considered. Empirical CDFs computed for projected values of low (Q5), medium (Q50) and high (Q95) flows show that, for the two selected catchments, there is a general projected decrease in all the streamflow magnitudes, but bias in the representation of the streamflows during the control period 1961-1990 hamper the assessment of reliable quantitative projections for low and medium flows, whereas projected decreases for high flows range from 0 to 60%, depending on the catchment and the climate scenario considered.