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Climate and hydrological uncertainties in projections of flood and low-flows in France

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Changes in river flows are associated with different types of uncertainties, due to an imperfect knowledge of both future climate and rainfall-runoff processes. Due to computational constraints, impact and adaptation studies unfortunately cannot always afford to perform a detailed analysis of all these uncertainties. In that case, the modelling efforts have to focus on the most relevant source of uncertainty in order to provide the best estimate of the overall uncertainty.

As part of the national Explore2070 project, the present study thus aims at assessing the hierarchy of uncertainties in changes on river flow extremes at the scale of France. Amongst all possible sources of uncertainties, two are here considered: (1) the uncertainty in General Circulation Model (GCM) configuration, with 7 different models that adequately sample the range of changes as projected by the GCMs used in the IPCC AR4 over France, and (2) the uncertainty in hydrological model structure, with 2 quite different models: GR4J (Perrin *et al.*, 2003), a lumped conceptual model, and Isba-Modcou (Habets *et al.*, 2008), a suite of a land surface scheme and a distributed hydrogeological model.

The hydrological models have been run at more than 1500 locations in France over the 1961-1990 baseline period with forcings from both the Safran near-surface atmospheric reanalysis (Vidal *et al.*, 2010) and the GCM control runs downscaled with a weather type method (Boé *et al.*, 2006), and over the 2046-2065 period with forcings from all downscaled GCM runs under the A1B emissions scenario. Various high flow indices (annual maximum daily flow with return period of 10 and 20 years, the daily flow value exceeded 10% of the time) and low flow indices (annual minimum monthly flow with a 5-year return period, annual minimum 10-day mean flow with a 2-year return period, the daily flow value exceeded 95% of the time) as well as seasonality indices have been computed for both periods.

An analysis of variance has been performed for each river flow index and at all stations shared by the two hydrological models (around 500) in order to assess the two considered sources of uncertainties in index changes as well as their hierarchy. Results first show spatial differences in the amount of sampled uncertainties due to both sub-regional climate specificities and catchment properties. The analysis of hierarchy between climate and hydrological uncertainties show striking differences (1) over France for a single index and (2) between different indices. The part of uncertainty relative to the hydrological response for example appears to be much more important for low-flow indices than for high-flow indices.

Experiments have additionally been performed to possibly reduce the overall uncertainty by weighting combinations of GCM and hydrological model through their ability of reproducing observed river flow extreme values over the baseline period.

The results of this study will help to define the relevant hydrological scenarios to be used in the adaptation part of the Explore2070 project for deriving national-scale adaptation strategies.

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