A distributed hydrological model to assess the impact of global change on water resources in the Rhône catchment

Un modèle hydrologique distribué pour étudier l'impact du changement global sur la ressource en eau dans le bassin versant du Rhône

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RÉSUMÉ

Le Rhône et ses affluents se caractérisent par une grande diversité de régimes hydrologiques et des modifications parfois profondes de ces régimes par des activités humaines. Le changement global pourrait modifier le fonctionnement du bassin et remettre en cause les règles de partage de la ressource, faisant émerger de nouveaux territoires en déséquilibre quantitatif quant à la ressource en eau. Le modèle hydrologique distribué du Rhône est un outil modulaire qui représente les processus hydrologiques majeurs sur le bassin versant, intègre la variabilité spatiale des paysages et des processus, et propose des représentations simples des principaux usages de l'eau (irrigation, alimentation en eau potable, déviation/stockage pour l'hydro-électricité). Il s'agit d'un outil de compréhension et d'aide à la décision pour comparer les effets d'évolutions climatiques ou socio-économiques, et tester des stratégies d'adaptation. Ses performances sont pour l'instant raisonnables et ont conduit à réaliser de premiers tests de scénarios simples.

ABSTRACT

The Rhône river catchment is characterized by a wide variety of hydrological regimes that are also deeply modified by human activity. In order to study the impact of global change on the water resources of the catchment, a distributed hydrological modelling tool has been developed. It represents the major hydrological processes in the catchment and their natural spatial variability. It also incorporates simple representations of three major water uses : irrigation, drinking water uptakes and dam management for hydropower production. It is being used to test the impact of climate change projections and water management scenarios It aims at bringing a comprehensive insight to such a complex catchment's behaviour, as well as becoming a decision support tool. Although it can still be improved, the model's performance is fairly good and first simple global change scenarios could be tested.

MOTS CLES

Distributed hydrological model, climate change, water management, Rhône

1 INTRODUCTION

The Rhône river catchment is characterized by a wide variety of hydrological regimes that are also deeply modified by human activity. The catchment water is crucial to many activities, including industry, agriculture, and drinking water supply in highly populated areas. Global change could alter the behaviour of the catchment and generate stress on the water resource in some of its constitutive regions. A distributed hydrological modelling tool has been developed with the objective of representing the major hydrological processes in the catchment, their natural spatial variability, and also the major water uses : irrigation, drinking water uptakes and dam management for hydropower production. It is being used to test the impact of climate change projections and water management scenarios.

2 MODEL DESCRIPTION AND SETUP

The model is called J2000-Rhône. It is based on the J2000 model that was developed in Germany for the European Water Framework Directive (Krause et al., 2006). J2000 is a process-oriented model that represents the main hydrological processes in a simplified, yet physically meaningful way. It considers rain/snow partition, interception, evapotranspiration, snow accumulation and melting processes, infiltration in soils, surface runoff, groundwater recharge and routing in the hydrographic network. It is fully distributed and uses irregular Hydrological Response Units as elementary modelling units. New components were added to J2000-Rhône to represent water uses :

- Irrigation uptakes are calculated on the basis of plant water requirements for each HRU where irrigation is activated. It takes into account the type of crop, rooting depth, leaf area index, irrigation period during the year, irrigation type and of course water availability.
- Drinking water uptakes are calculated according to an econometric model that uses data such as population, climate, population incomes, nature of housing etc.
- Dam management operations are reproduced using objective functions for filling or emptying of the dam reservoirs. These objective functions are estimated through a comparison of natural and influenced flow (Cipriani and Sauquet, 2017).

The model is set up using mostly freely available data : ASTER DTM, Corine Land Cover land use map, Soil European Database, INSEE… But other sources of data were also used in particular RGA (Recensement Général Agricole) for irrigation. The SAFRAN reanalysis from Meteo-France is used as climate forcing. For model evaluation, a set of 234 stations were selected from the Banque Hydro database. Parameters were initially assigned according to existing information and the literature. The model was iteratively improved in order to better reproduce observed discharge while keeping the physical meaning of the parameters (Branger et al., 2016).

3 RESULTS

J2000-Rhône simulates daily flows with a fairly good performance for the present period (1987-2012) (see Fig. 1). It is less successful in karstic zones where specific hydrological processes are not taken into account, and in some of the mountain zones where we suspect the SAFRAN meteorological data to underestimate the amount of precipitation.

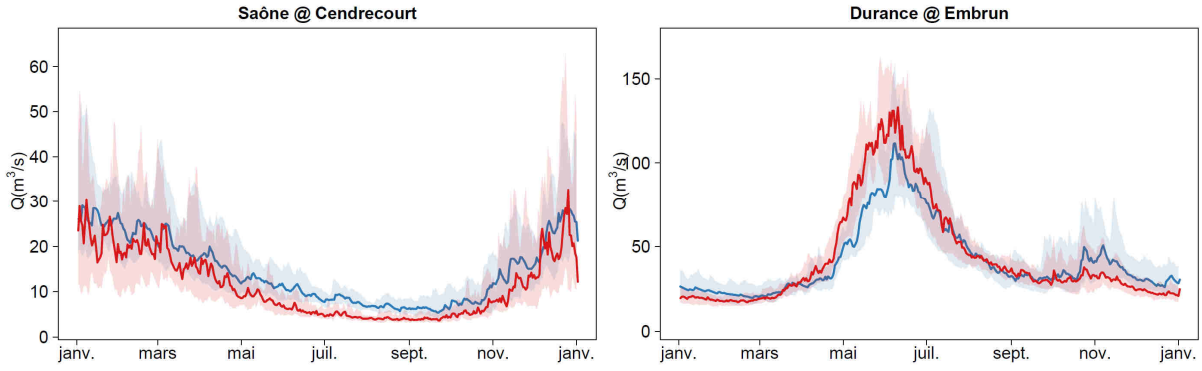

Figure 1 : Median daily flows and 1st – 3d quartile intervals at two stations : Saône at Centrecourt (1170 km2) and Durance at Embrun (2170 km2) for the period 1987-2012. Simulation : blue ; Observation : red.

Sensitivity of water resource and water uses in the Rhône catchment to global change scenarios was tested. Future climate projections were taken from ALADIN simulations for three different scenarios (RCP 2.6, 4.5, and 8.5) available on the DRIAS portal (www.drias-climat.fr). Simple irrigation and drinking water uptake scenarios were set up. Although the results have no predictive value due to critical uncertainties in climate and e.g. demographic scenarios, they suggest that the evolution of water uses may have more impact than climate change itself, in particular for the most pessimistic climate scenario (RCP 8.5, see Fig. 2).

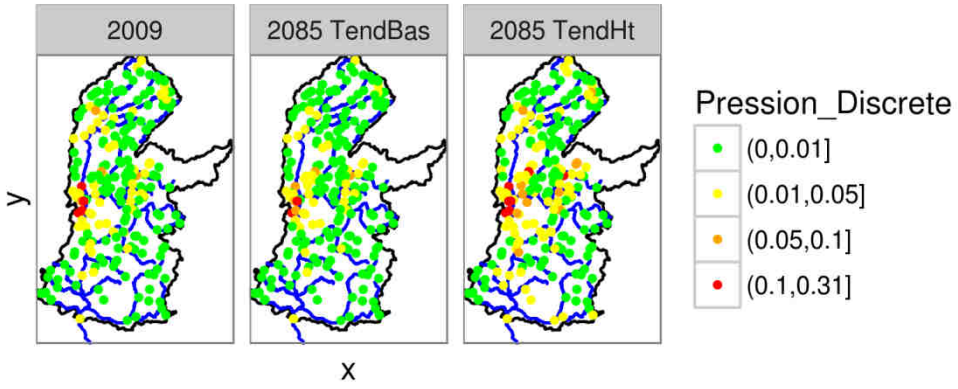

Figure 2 : Estimation of the pressure on the water resource defined as the ratio of combinted irrigation and drinking water uptakes over available water for the present time (year 2009, left) and for the 2070-2100 horizon (2085) with climatic projection RCP 8.5 and two contrasted water use scenarios (middle and right).

4 CONCLUSIONS AND PERSPECTIVES

The J2000-Rhône is a modelling tool aiming at providing physically sound simulations of the hydrological behaviour of the Rhône catchment, taking into account three major water uses in the catchment. It is open-source and freely available for scientific or operational use. So far it has showed potential for studying the coupled impact of climate change and water management scenarios.

The future of J2000-Rhône includes improvements of the parameterisation of hydrological processes, for which several projects are already under way. The representation of water uses can also be improved, provided the required data are available, in particular the location of water uptake and release. It will also be possible to test more (and more realistic and /or detailed) future scenarios, in particular with the help of water management agencies.

ACKNOWLEDGEMENTS

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