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Linking Pan-European data to the local scale for decision making for global change and water scarcity within water resources planning and management

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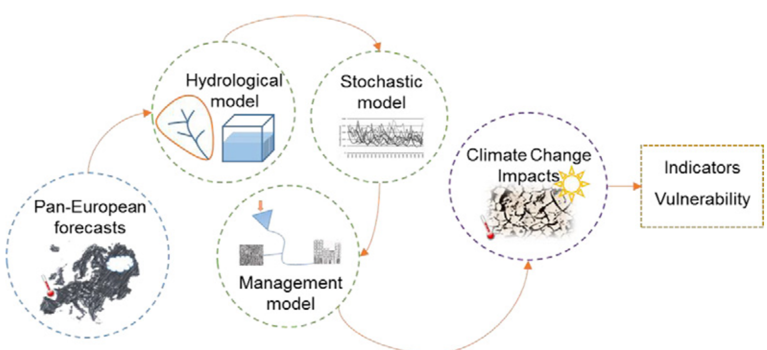
HIGHLIGHTS

- A new approach is provided to link Pan-European data to local scale within CC.
- A modeling chain is developed to improve long-term measures for basin management.
- Results are probabilities in order to assess the reliability of water supplies.
- The reduction in precipitation from the 80s is not contemplated in RCM projections.

GRAPHICAL ABSTRACT



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ABSTRACT

This study focuses on a novel type of methodology which connects Pan-European data to the local scale in the field of water resources management. This methodology is proposed to improve and facilitate the decision making within the planning and management of water resources, taking into account climate change and its expected impacts. Our main point of interest is focused on the assessment of the predictability of extreme events and their possible effects, specifically droughts and water scarcity. Consequently, the Júcar River Basin was selected as the case study, due to the ongoing water scarcity problems and the last drought episodes suffered in the Mediterranean region.

In order to study these possible impacts, we developed a modeling chain divided into four steps, they are: i) data collection, ii) analysis of available data, iii) models calibration and iv) climate impact analysis. Over previous steps, we used climate data from 15 different regional climate models (RCMs) belonging to the three different Representative Concentration Pathways (RCPs) coming from a hydrological model across all of Europe called E-HYPE. The data were bias corrected and used to obtain statistical results of the availability of water resources for the future (horizon 2039) and in form of indicators. This was performed through a hydrological (EVALHID), stochastic (MASHWIN) and risk management (SIMRISK) models, all of which were specifically calibrated for this basin.

The results show that the availability of water resources is much more enthusiastic than in the current situation, indicating the possibility that climate change, which was predicted to occur in the future has already happened in the Júcar River Basin. It seems that the so called "Effect 80", an important decrease in water resources for the last three decades, is not well contemplated in the initial data.

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1. Introduction

Climate change is a natural process that has been accelerated by human influence, due to the huge amount of emissions of greenhouse gases into the atmosphere. It is related to human development, growth and consumption patterns (Vargas-Amelin and Pindado, 2014), and currently these emissions are the highest in history (IPCC, 2014). However, it is not the only factor that contributes to climate change, as could volcanic activity and ocean circulation also be contributors, however burning fossil fuels and industrial processes have been recognised by scientific communities as the main contributors that have increased the concentration of CO_2 in the atmosphere (IPCC, 2014), consequently these factors could be the main contributors that are responsible for the increase of the Earth's temperature.

In addition, it is known that the Mediterranean area is becoming drier, and therefore more vulnerable to wildfires and drought. There is an elevated probability that Mediterranean river basins, as many other semi-arid regions, will suffer an important decline in water resources availability attributable to climate change (Vargas-Amelin and Pindado, 2014). In the coming years, it is expected that the increasing water demand in combination with water scarcity due to climate change will intensify the current water stress.

Many studies suggest that climate change will amplify the frequency of current problems (Bates et al., 2008), and within Europe, Spain is one of the most exposed countries to climate change, caused by its socio-economic and geographic features (MMA, 2005). Moreover, the general pattern of the projected models indicate a decrease in precipitation and an increase in temperature for this area (Estrela et al., 2012; Garrote, 2009), within its limitations regarding the uncertainty, the spatial resolution, the projections range and their complexity among others. This could lead to an intense competition between different user groups and sectors due to the possible prolonged periods of water scarcity where water is already limited today (van Vliet et al., 2015), all related to social, economic and environmental impacts. Thus, it seems clear that the adaptation to climate change necessarily implies the participation of scientists, governments and society.

In this sense, the European Union (EU) Roadmap on climate services (European Commission, 2015) represents the convergence between society's actionable research and the faculty of the climate research community to support personalized knowledge, information and data (van den Hurk et al., 2016). Therefore, if society is aware of the existence of a reliable forecast, then the anticipation for extreme events could become a very operative adaptation measure (van den Hurk et al., 2016).

Knowing all this, a new methodology based on a modeling chain (hydrological, stochastic and management models) is presented in this paper with the aim of creating a link between climate services and decision-making in water resources planning and management at the river basin scale. It is based on the application of a decision support system, in order to support adaptation, mitigation and reduce risk disasters. To accomplish with this objective, the assessment of the effects of global change in the Júcar River Basin (east of Spain) was performed to evaluate if current urban and agricultural requirements could be suitably met under future changing scenarios.

This process begins with Pan-European climatic data from the E-HYPE hydrological model belonging to the SWICCA Copernicus Project (Service for Water Indicators in Climate Change Adaptation). This projects aim is to bridge the gap between institutes who provide climate-impact data on one side, and water managers and policy makers on the other. As several authors have highlighted (Donnelly et al., 2016), the E-HYPE model presents some inconveniences in the Mediterranean area, presenting some gaps in evapotranspiration, aquifers and water extraction among others (Donnelly et al., 2016). Thus, it was necessary to correct climate data and use a modeling chain specifically calibrated for this area. The importance of this is to obtain reliable results that should be able to detect future periods of drought and avoid the possible impacts associated with them. In this sense, it could be possible to know of droughts in advance and make the right decisions by preventing impacts to water resources availability in the future. In addition, it could be incorporated to other countries or river basins affected by water scarcity into water planning.

2. Materials and methods

The methodology presented in Fig. 1 was developed to connect Pan-European data to the local scale in order to assess the state of the system and to propose the measures required in future periods, taking into account the impacts of water scarcity due to global warming. It is represented by two pathways (depending on the origin of the data), which interact with one another and finally converge in a final step.

Pan-European and historical data collection are the first step of the methodology. Once data series are obtained, a reference period is selected and both data are compared to know the accuracy of the forecast and to obtain a bias correction coefficient for correcting future scenarios. On the other hand, historical data are also used for model calibration. Firstly, the stochastic model is employed to generate multiple streamflow series equiprobable with the historical ones. Secondly, the previous generated series are used to analyze multiple runs of the water management model, obtaining multiple different management results. Both ways are related for the correction of the stochastic model, which is done with the properties of corrected future scenarios. Finally, the climate impact analysis is performed for different regional climate models (RCMs) in order to obtain several indicators and asses the vulnerability of the system, with the aim of applying some adaptation measures and mitigate the impacts of climate change. The application of these measures can be considered as a new scenario, because of that, the final step is a close-loop process. This procedure is explained below in more detail, it is divided in several steps, which are: 1- Data collection; 2- Analysis of the available data; 3- Models calibration; 4- Climate impact analysis.

2.1. Step 1: Data collection

The data required come from Pan-European and local databases, it includes: river flows, precipitation, potential evapotranspiration and temperature (minimum, average and maximum).

Pan-European data come from the SWICCA Copernicus project, which has developed a website that enables the download of climate, hydrological and indicators data from all over Europe (http://swicca.climate.copernicus.eu/) at different space and time resolutions. In this sense, based on the most appropriate space resolution for this research (catchment resolution, 215 km^2), data from the E-HYPE hydrological model (Hundecha et al., 2016) were used. E-HYPE uses global databases and Global Monitoring for the Environment and Security (GMES) satellite products as input data and then is forced by the European Centre for Medium-Range Weather Forecasts (ECMWF) and the Swedish Meteorological and Hydrological Institute (SMHI) to calculate the water balance, hydrological variables and daily discharge for the entire continent (Hundecha et al., 2016). Some of the uses of this model are hydrological forecasts, water allocation, predictions for ungauged basins, climate change impact assessments and hydraulic flood models.

Therefore, we disposed the daily time series of precipitation, temperature and river flows from the period of 1971–2100 (using the years 1971–2000 as a reference period) and for 11 different RCMs, belonging to the three Representative Concentration Pathways (RCPs) (2.6 mitigation, 4.5 stabilization and 8.5 high greenhouse gas scenarios). In Table 1, the different ensembles and their origin (Global Climate Model and Institute) are presented. On the other hand, historical data come from the Spain02 database (Herrera et al., 2012), conformed by an observations grid of approximately 20 km of spatial resolution for the period 1950–2003. Thus, we dispose data from the same reference period on which we are going to analyze on both E-HYPE model, as well as Spain02, from 1971 to 2000.