EXPLORING THE FUTURE IMPACTS OF CLIMATE CHANGE ON THE WATER RESOURCES OF FRANCE

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Abstract: A new version of the Safran-Isba-Modcou (SIM2) hydrometeorological system is used to study the climate change impact on the water resources of France, as well as the impact on the vegetation, which is possible thanks to the use of the prognostic vegetation biomass option (ISBA-A-gs). Using 6 different Regional Climate Models (RCM) and three different emission scenarios (RCP26, RCP45 and RCP85), the first preliminary results for streamflow show a spatial contrast, with an increase in the north and a decrease in the south, especially for the RCP85. For the rest of emission scenarios, the results are more uncertain. For the Leaf Area Index (LAI), an increase in the mean climatological values are projected for the three emission scenarios, especially during the peak season.

Keywords: Water Resources; Climate change; Streamflow; Leaf Area Index

Introduction

According to the latest Assessment Reports (AR5, AR6) of the Intergovernmental Panel of Climate Change (IPCC) (IPCC 2013, 2021), an increase in the probability of heatwaves and droughts is expected in the future. Both phenomena can have several impacts on water availability for society, agriculture and/or vegetation.

Previous studies focusing on the impact of climate change on the water resources over France concur in projecting a decrease in precipitation, especially in southern France, also showing a decrease in soil moisture and runoff, but a high uncertainty remains (Boe et al. 2009, Soubeyroux et al. 2011,Chauveau et al. 2013, Dayon et al. 2018).

Our aim is to contribute to study this uncertainty by using a new version of the Safran-Isba-Modcou (SIM) hydrometeorological system. The use of the new version of SIM (SIM2) is a clear improvement over previous studies, as it uses more realistic physics, and surface parameters description providing a better assessment of the different systems of the water cycle. In addition, we also use the prognostic vegetation biomass option in the simulations (ISBA-A-gs). This means that the evolution of the vegetation conditions throughout the year is linked to the specific meteorological and soil conditions of that year, not to an imposed climatology. This is a relevant novelty regarding the previous studies over France, and a part from its relevance in the hydrological cycle it gives us the opportunity to analyze the impact of climate change on the vegetation activity and the water balance components. The ability of ISBA-A-gs to simulate vegetation activity, focusing on Leaf Area Index (LAI) was previously tested at global scale (Gibelin et al. 2006) and at Euro-Mediterranean region (Szczypta et al., 2014). A previous study focusing on the impact of climate change on vegetation cycle over France also exist (Laanaia et al., 2016), but using CMIP3 emission scenarios.

This is a work in progress project that started in the frame of a Make Our Planet Great Again (MOPGA) postdoctoral grant.

1. Data and methods

6 different regional climate models (RCMs) (Table 1) from Coordinated Regional Climate Downscaling Experiment (CORDEX) (Giorgi et al 2009) and three different emission scenarios (Representative Concentration Pathway (RCP) 2.6, 4.5 and 8.5) were used as climate forcing data. The models were bias-corrected using the ADAMONT method applied to the RCM data (Verfaillie et al 2017) within the Explore2 project, and hourly climate data were obtained. CO2 concentration values were obtained in parts per milion (ppm) for the different emission scenarios and converted to kg/m3 to be used in the simulations.

The simulations cover the period 1971-2100, being 1971-2005 period forced by historical RCM, with a 10-year spin-off at the beginning of this period. The 2005-2100 is forced by climate projections. For the historical period 6 different simulations are obtained and for the projected period 18 different simulations are obtained (6 RCMs x 3 RCPs).

A new version of Safran-Isba-Modcou (SIM2) was used, activating the prognostic vegetation biomass option in the simulations (ISBA-A-gs). ISBA-A-gs was used for active vegetation, meaning that vegetation phenology adapts to simulated atmospheric and soil conditions. Using values of Leaf Area Index we plan to calculate the impact of climate change on the onset, senescence and the period of activity of the vegetation

We obtained daily data from simulations, but for most of the variables we converted the data into monthly and sub monthly values. The sub monthly periods are defined as a quasi 10-daily periods, splitting each month in 3 different periods (1-10, 11-20, 21-end). Therefore, the last period of each month can have a variable number of days (8 to 11). While this can be a problem for comparison between different sub-monthly periods, this facilitates the interanual comparison of the data. Nevertheless, first preliminary analysis are shown in a yearly or monthly basis.

For this first preliminary analysis, the 1981-2000 period from the historical simulations is used as a reference to calculate the difference with three different periods in the future: 2040-2060, 2060-2080 and 2080-2100.

Table 1. Regional Climate Models used in the simulations.

Acronym	*GCM*	*GCM Institution*	*RCM*	*RCM Institution*
CNRM-ALAD	CNRM-CM5	CNRM	ALADIN63	CNRM
CNRM-RACM	CNRM-CM5	CNRM	RACMO22E	KNMI
EC-RACM	EC-EARTH	ICHEC	RACMO22E	KNMI
EC-RCA4	EC-EARTH	ICHEC	RCA4	SMHI
MPI-CCLM	MPI-ESM	MPI	CCLM4-8-17	CLMcom
MPI-REMO	MPI-ESM	MPI	REMO2009	CSC

2. Results

2.1.Streamflow

For two different periods (2040-2060 and 2080-2100) and two different emission scenarios (RCP45 and RCP85), Figure 1 represents the ensemble mean of the projected changes in the mean annual streamflow compared to the 1980-2000 period for a selection of 200 gauging stations. RCP85 is the scenario showing more relevant changes, with a contrasting north-south pattern. While an increase in the streamflow is expected in the north, a decrease is expected in the south.

RCP85 scenario detects this pattern in the two different time periods, but the RCP45 only detects this pattern at the end of the century (2080-2100). The magnitude of the projected change is also greater for the RCP85 scenario at the end of the century, showing percentage changes in the range of 10-15%, or even higher.

On the other hand, RCP45 scenario for the 2040-2060 show a high uncertainty in a large number of gauging stations, as it is reflected by the large number of small gray dots that appear in Figure 1. These dots represent those gauging stations in which three of the six simulations show a different sign in the difference than the ensemble mean.

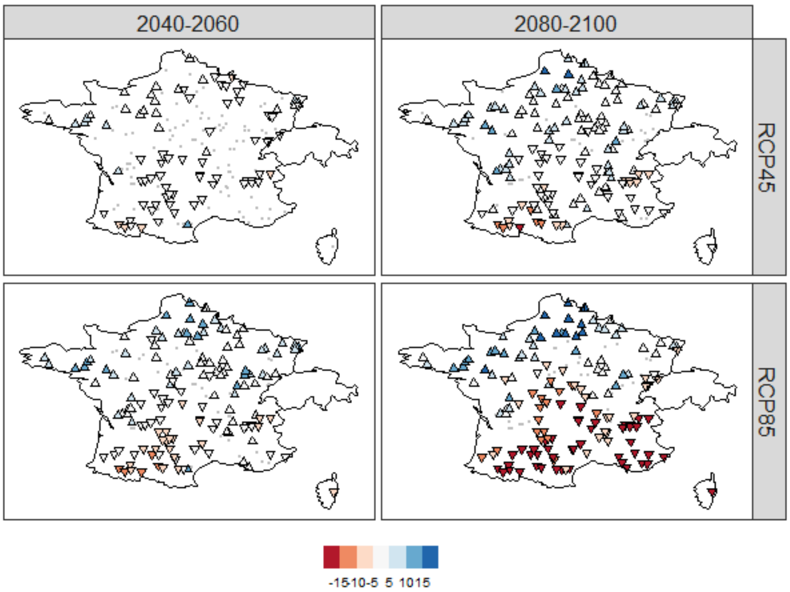

figure 1- Percentage of changes of annual streamflow at 200 gauge stations in France for two different emission scenarios (RCP45 and RCP85) and two different time periods (2040-2060 and 2080-2100), compared to historical simulation for the 1980-2000 period. Grey dots represent gauging stations with high uncertainty.

Figure 2 represents the change (in percentage) at 4 specific locations of the Loire, Rhone, Seine and Garonne rivers, for the three emission scenarios and three time periods.

Again, the largest changes are projected under the RCP85 scenario at the end of the century (2080-2100). While a high decrease is obtained in the Rhone and Garonne, an increase is projected in the Seine, which confirms the north-south contrast above mentioned. Interestingly, the RCP26 scenario show an increase in the streamflow at these 4 different locations.

The contrasting differences between different emission scenarios confirms the high uncertainty related with the future emissions. RCMs are also a relevant source of uncertainty, as it can also be seen in Figure 2. In some cases, for example the Rhone streamflow for the 2040-2060 period, the Whisker plots for the three emission scenarios show that half of the models project a slight increase in the streamflow and half of the models project a slight decrease. Further analysis are required to better understand the specific role of the different sources of uncertainty.

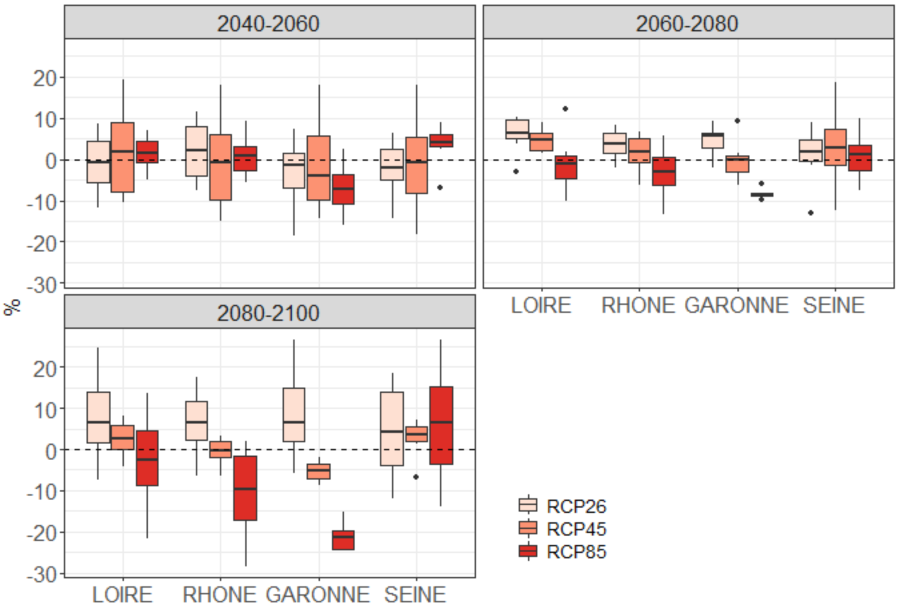

figure 2- Whisker plots representing percentual changes in mean anual streamflow at four rivers of France : Loire, Rhone, Garonne and Seine.

2.2. Leaf Area Index (LAI)

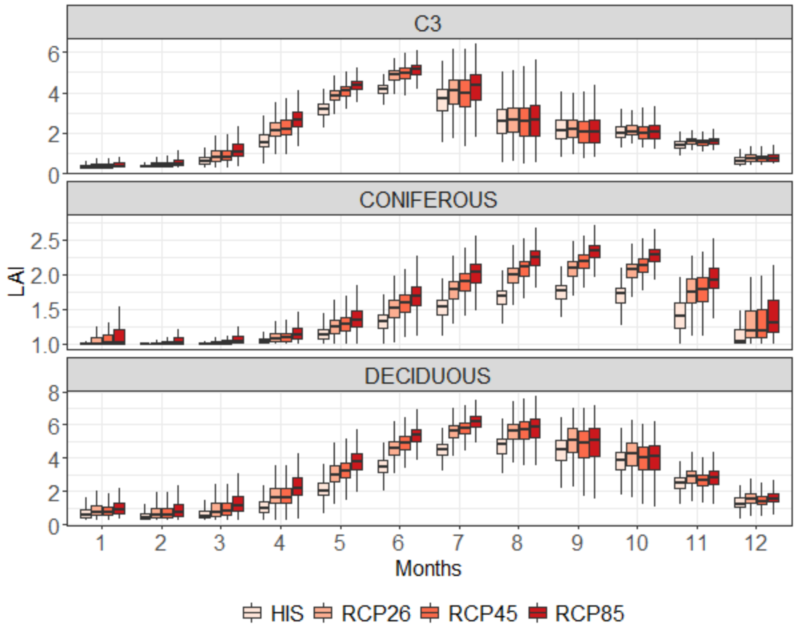

figure 3. Whisker plot representing the Leaf Area Index (LAI) evolution values for different emission scenarios for the 2040-2060 period at the different grid points over France.

Figure 3 represents a comparison of the monthly evolution of LAI values for three different patches (C3 crops, coniferous and deciduous) between the 2040-2060 and the 1980-2000 historical simulations.

For the three emission scenarios, the projected values of LAI for the future show the same seasonality as the historical values, with some differences between the different patches. In the three cases, a general increase is projected during the vegetation activity period. For C3 crops and deciduous, this increase is mainly expected in spring and summer while for the coniferous this increase is projected from spring to autumn.

The increase in the mean values during spring could imply an earlier onset of the vegetation, but further analysis are required to confirm this point.

Conclusion

In the first preliminary results of the project, we can detect an impact of climate over the water resources of France but also on the vegetation activity (thanks to the use of ISBA-A-gs). Projected changes in the streamflow are very dependent on the emission scenarios and are more evident for the end of the century.

On the other hand, even low level emission scenario (RCP26) seem to have an effect on vegetation activity, showing higher values of LAI. Further analysis are required to better understand the origin of this changes, which could be related with the fertilization of CO2 or changes in climate/soil variables.

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