Towards improving the performance of water-energy systems by integrating large-scale climate services indicators

Anthony Lemoine, Maria-Helena Ramos

TOWARDS IMPROVING THE PERFORMANCE OF WATER-ENERGY SYSTEMS BY INTEGRATING LARGE-SCALE CLIMATE SERVICES INDICATORS

Vers l'amélioration des performances des systèmes eau-énergie en intégrant des indicateurs de services climatiques à large échelle

Anthony Lemoine[1], Maria-Helena Ramos

Irstea, UR HYCAR, 1 rue Pierre-Gilles de Gennes, F-92761 Antony, France
anthony.lemoine@irstea.fr, maria-helena.ramos@irstea.fr

ABSTRACT

The impacts of climate change on the hydrological cycle are a growing concern among water managers, particularly in the hydroelectric sector. To meet the growing demand for impact assessment and adaptation strategies in the water sector, climate services are flourishing across Europe, particularly in connection with the Copernicus Climate Change Service (C3S). It is therefore necessary to study the use of climate services available on a regional, or even continental, scale for local decision-making in the hydroelectric sector. The first part of this study presents an overview of the main European climate services that can be useful for hydropower planning and management in the context of future climate scenarios, climate change and adaptation. Secondly, we present an example of the possible use of the information provided by the climate services to inform future changes in monthly flows, which are crucial information to water reservoir management. More particularly, we use a set of GCM/RCM simulations from the SWICCA and the Clim4Energy climate services over the Dordogne river basin to characterise the possible flow evolution in the context of future climate. The conclusions drawn from this work and the perspectives envisaged for the future are mentioned at the end.

KEY WORDS

Climate, climate services, hydropower, water resources, climate projections.

RESUME

Les impacts du changement climatique sur le cycle hydrologique suscitent une préoccupation croissante au sein des gestionnaires de l'eau, en particulier dans le secteur hydroélectrique. Pour répondre à la demande croissante en estimation des impacts et à la demande de définition de stratégies d'adaptation dans le secteur de l'eau, les services climatiques fleurissent à travers l'Europe, en particulier en lien avec le service « Copernicus Climate Change » (C3S). Il est donc nécessaire d'étudier l'utilisation de services climatiques à l'échelle régionale, voire continentale, pour la prise de décisions à l'échelle locale dans le secteur hydroélectrique. Dans une première partie de cette étude, nous présentons une vue d'ensemble des principaux services climatiques européens pouvant être utiles à la planification et à la gestion hydroélectriques dans le cadre des scénarios de climats futurs, du changement climatique et de l'adaption à celui-ci. Dans un second temps, nous présentons un exemple d'utilisation possible de l'information fournie par les services climatiques pour renseigner sur les changements futurs de débits mensuels, qui sont des informations cruciales pour la gestion des réservoirs d'eau. Plus particulièrement, nous utilisons un ensemble de simulations GCM/RCM issues des services climatiques SWICCA et Clim4Energy sur le bassin de la Dordogne pour caractériser les évolutions possibles de débits dans le futur. Les conclusions tirées de ce travail et les perspectives envisagées pour la suite sont discutées.

MOTS-CLEFS

Climat, services climatiques, hydroélectricité, ressources en eau, projections climatiques

[1] Corresponding author

1. INTRODUCTION

The impacts of climate change on the hydrological cycle are a growing concern within the water management community, particularly in the hydropower sector, which has to cope with rapidly changing water resources and an increasingly competitive electricity market [Kumar et al., 2011; Schaefli, 2015]. To meet the growing demand for impact assessment and adaptation strategies in the water sector, climate services are flourishing across Europe, particularly in conjunction with the European Commission's Copernicus Climate Change Service (C3S, https://climate.copernicus.eu/). Some examples of services set up under C3S are, for instance, the SWICCA (Service for Water Indicators in Climate Change Adaptation, http://swicca.climate.copernicus.eu/) and the Clim4Energy (https://climate.copernicus.eu/clim4energy) services.

The provision of climate services, however, does not guarantee their widespread use by climate-sensitive economic sectors, including the hydropower sector [Hurk et al., 2016; Soares and Dessai, 2016], hence the need to develop pathways and techniques that allow and facilitate the integration of climate services into current users' decision-making tools. For service providers and users, the overall aim is to improve the quality and usability of several climate services, by taking into account the main needs of the different water-related sectors.

The current state of development of climate services for water indicates that the following improvements are needed to increase adoption and satisfaction of users of these services: (a) indicators and resolution of indicators provided by climate services must better meet a wider range of user needs; (b) large-scale climate services data must be reliable at the local decision-making scale; and (c) service guidances and visualization tools should better reflect the wider range of user needs.

This study aims to contribute to the use of climate services available on a regional, or even continental, scale for local decision-making in the hydroelectric sector. In section 2, we present an overview of the main European climate services that can be useful for hydropower planning and management in the context of future climate scenarios. Section 3 illustrates an example of how data can be extracted from climate services. Finally, we present some conclusions and some way forward in section 4.

2. CLIMATE SERVICES

AllEnvi (National Alliance for Research on the Environment) defines climate services as “all the information and services that make it possible to evaluate and qualify the past, present or future climate, to assess the vulnerability of economic activities, environment and society to climate change and provide elements for undertaking mitigation and adaptation” [AllEnvi, 2014]. Climate services are also defined in this way in the *European research and innovation Roadmap for Climate Services* [EC, 2015]. In this guide to the establishment of a European market for climate services, it is also recognised that “climate services have the potential of becoming a supportive and flourishing market, where public and private operators provide a range of services and products that can better inform decision makers at all levels, from public administrations to business operators, when taking decisions for which the implications of a changing climate are an issue”.

This initiative has helped to strengthen the development or contribute to the merging of several European climate services brought together within the Climate Change Copernicus Service (C3S). One originality of the C3S is to put together climate services by sectors of activity in order to facilitate decision support at both societal and business levels. The C3S Sectoral Information System divides climate services into the following sectors of activity: water, energy, agriculture and forestry, health and infrastructure, and insurance. Particularly for the energy sector, Ramos et al. [2016] highlight the fact that energy system operators seek to optimize production and improve their resistance to extreme weather events and climate change. The use of climate services by hydropower managers would therefore be one of the pathways to meet their expectations in terms of making better-informed decisions in the context of climate change.

In the case of hydropower, it may be possible to use climate services specifically developed to the energy sector (e.g., Clim4Energy, ECEM), but also services more generally designed to satisfy the needs of the water resource management sector (e.g., EDgE, SWICCA). These climate services do not always offer the same climatic information and do not provide data with the same spatial and temporal resolutions. This can make the process of extracting information for local decision-making more laborious.

A first step when choosing among different climate services to inform water-energy systems is to identify what each service offers. In order to provide an overview of the available portals, we selected six climate services and compared them in terms of their climatic information as well as their spatial and temporal resolutions. The climate services presented are Clim4Energy, ECEM, EDgE and SWICCA as well as the two portals of Météo-France, Drias and ClimatHD. Figure 1 presents the main climatic variables or indicators available at each climate service provider, separated by sector of activity that is directly related to hydroelectricity or that may influence hydroelectricity decisions (i.e., sectors of water, energy and agriculture). Figure 2 presents the different spatial and temporal resolutions proposed by the climate services mentioned above.

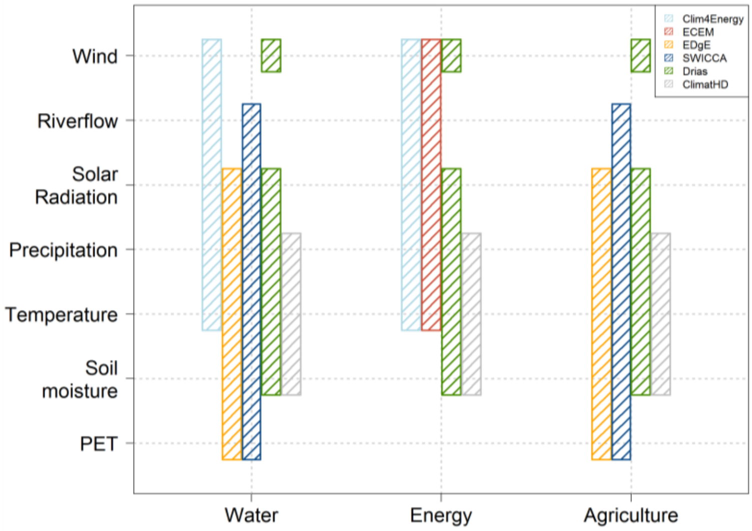

Figure 1: Main climatic variables or indicators by sector of activity for six climate services

We can see that European climate services usually cover more specific variables or indicators for one or two sectors: e.g., the Clim4Energy portal can service the water sector and the energy sector with climatic data available for wind, solar radiation, river flow, precipitation and temperature. Similarly, the SWICCA portal offers climatic information that can be useful to the sectors of water and agriculture. The SWICCA service is the one that offers the widest range of climatic information. The French national climate services (Drias and ClimatHD) target a larger number of sectors, but without offering a wide range of specific variables and indicators: they cover precipitation, temperature, soil moisture and, in the case of Drias, also solar radiation and wind. In general, it seems that European portals search for providing more targeted information for particular sectors than the broader national portals.

In terms of spatial and temporal resolutions (Fig. 2), the Clim4Energy, EDgE, SWICCA and Drias portals offer a higher spatial resolution. The finer scale available on the ECEM and ClimatHD portals stops at the region or cluster scale. It should also be noted that the SWICCA portal is the only one to offer high spatial and temporal resolutions at the same time.

Finally, we note that there are many other climate services that target other specific sectors and also include different climatic information. They were not shown here since we focused only on services targetting more specifically the energy sector (or closely-related sectors) and providing comparable information on climate projections. An example of the use of such information is provided in the next section for two climate services: SWICCA and Clim4Energy.

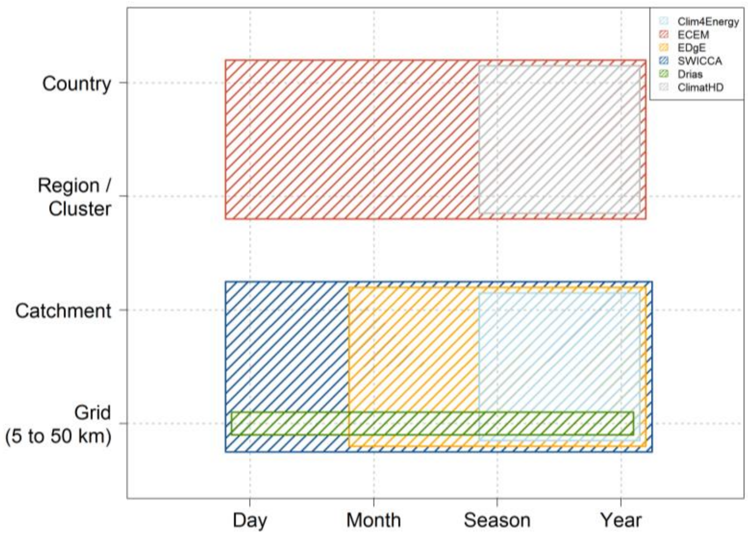

Figure 2: Spatial and temporal resolutions of climatic information for six climate services

3. USE OF CLIMATE SERVICES FOR THE HYDROPOWER SECTOR

Climate services offer many climatic information such as temperature, precipitation and riverflow. In general, the portals make available observations or reanalyses for a reference period and for different (future) periods of climate projections. For example, the Clim4Energy portal offers data on flow anomalies, regarding the reference period of 1981-2010, for the "present" climate (2001-2030), the "near future" climate (2016-2045) and the "mid-century" climate (2036-2065).

Troccoli et al. [2014] state that it is relevant to focus on the development of robust and representative "climate-water-energy" performance indicators. With this in mind, we explored the information from climate services that can potentially be useful to a hydropower manager. The geographic case study selected is in the Dordogne River basin, which has many hydropower installations, with a particular interest in the evolution of flows in future climate. The river location considered is the Dordogne river at Argentat. The SWICCA and Clim4Energy climate services were used as example in this study. They propose indicators of the evolution of river flows for several future periods and for different greenhouse gas emissions scenarios. Here, we focused on the RCP 4.5 scenario. This is the scenario which is associated with the greatest number of GCM/RCM projections available in the SWICCA portal. Moreover, it is also the closest scenario to the recommendation of the Paris agreement towards limiting global warming to +2°C for the end of the century.

For a set of 5 GCM/RCM projections from SWICCA and 7 GCM/RCM projections from Clim4Energy (4 of them in common with the SWICCA service), we compared the projected evolutions of river flows according to each GCM/RCM pair for two future periods: the near future (2016-2045) and the mid-century period (2036-2065). The evolutions are given compared to a reference period (1981-2010). For Clim4Energy, we extracted, at the river location, the anomalies directly provided by the portal. For SWICCA, we extracted the flows at the river location and calculated the anomalies, using the same methodology described in the Clim4Energy portal. Figure 3 shows the results obtained. It presents the monthly percentage anomalies of the projected flow ratios for each GCM/RCM pair for the two future periods (relative to the reference period) and for the SWICCA and Clim4Energy data. Flow ratios are given by the ratio between projected flows and the long-term average flow given by the reference period. It is important to note that the anomalies presented in Fig. 3 are displayed in a cumulative way to facilitate the reading of the results. Only the increments of each model should be taken into account (represented by the width of each color code).

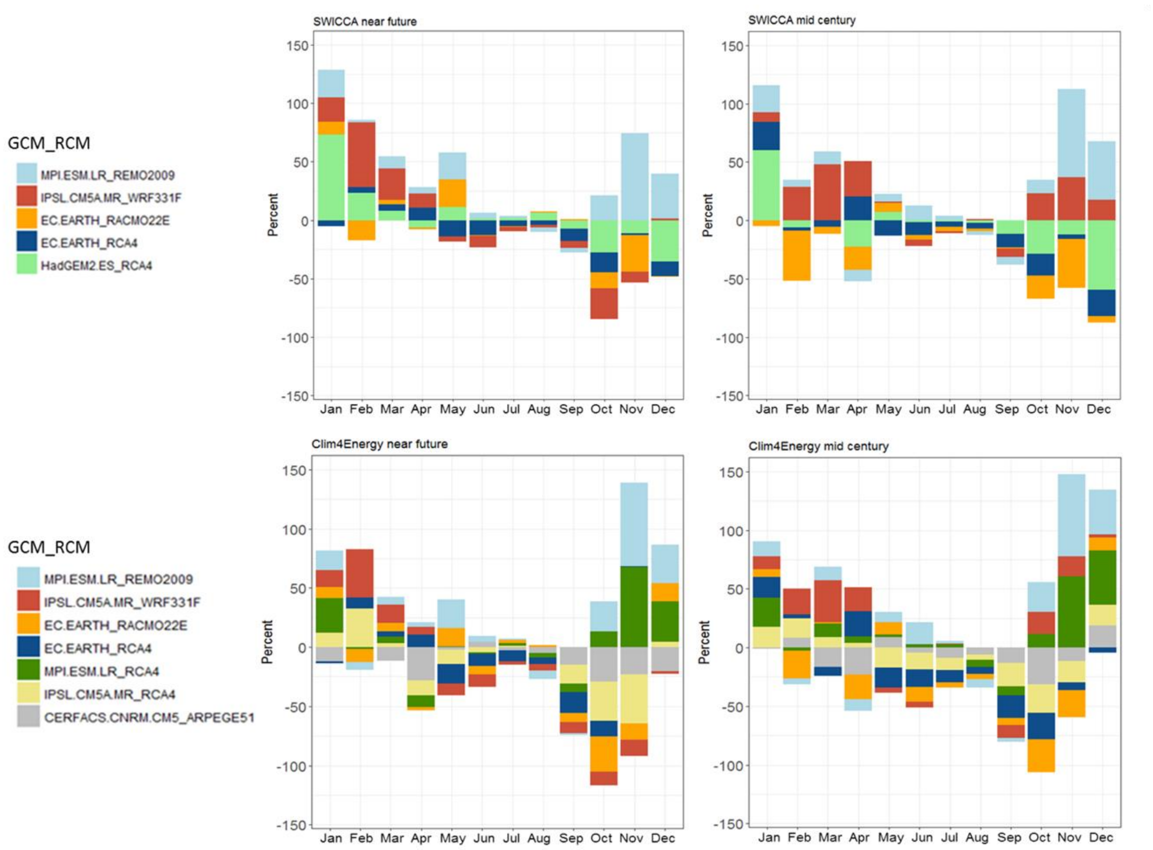

Figure 3: Monthly anomaly of projected inflow ratios of each GCM/RCM set extracted from SWICCA (top) and Clim4Energy (bottom) for two future periods, near future (2016-2045, left) and mid century (2036-2065, right), relative to the reference period (1981-2010)

The differences observed between the results from the GCM/RCM sets extracted from the two portals (SWICCA and Clim4Energy) are mainly due to the internal structure of the climate models used and the downscaling methods, since the same hydrological model (E-HYPE) is used in both portals. We can see that, for both future periods, the two sets display flow seasonality. The differences between the different pairs of GCM/RCM models are more important during the winter season than in summer. For the two future periods, we can see an increase in the dispersion between the different GCM/RCM pairs, even though they have the same RCP forcing.

These initial results seem to indicate that the management of the dam inflows in winter may be more complex to assess under future climate conditions, since it is in this season that the dispersion of the GCM/RCM pairs is most important. The results also highlight the importance of considering several climate services when evaluating future conditions for the management and planning of hydropower production. For example, for the mid–century period, the SWICCA portal set shows that there can be either an increase or a decrease in December flows, depending on the GCM/RCM considered, whereas the Clim4Energy portal set mainly shows an increase in the same monthly flows, and therefore also in the hydroelectric potential for this period.

4. CONCLUSION AND WAY FORWARD

Climate services provide data and tools to better understand climate change and its impacts on our society. They assist in the decision-making process, especially when it comes to adaptation and mitigation. However, there is a large variety of climate services available for decision-makers today, more or less targetting specific economic sectors and spatial and temporal resolutions, which can create barriers to their use. This multitude of data and information is not a guarantee of immediate use by dam managers. There is a crucial need today to better evaluate how regional and continental information from climate services can be efficiently used by local managers and decision-makers.

Climate portals provide essential information on climate projections for a variety of climatic variables. It is possible to access temperature, precipitation and flow projections, without the need of having large calculation infrastructures to run climate models locally. Climate portals can therefore be potentially useful for the range of applications of the hydropower sector, for small hydroelectricity and large reservoirs, but also for the energy sector, in general, including climate-related intermittent renewable energies. To facilitate the widespread use of climate services by the hydroelectric sector, it is important to develop indicators that can specifically address the main aspects that influence planning and decision-making in the sector. The next steps in this work will therefore focus on developing relevant indicators and test their usefulness in reservoir management. The overall aim is to learn how to extract from projections the most relevant information (in time and space) that climate services can offer to enhance hydropower management under uncertain future climate.

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