Water restrictions under climate change: a Rhone-Mediterranean perspective combining 'bottom up' and 'top-down' approaches"

Sauquet et al.

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This comment was written by a student in the MSc course ESS 401 Current topics in Earth System Science at the University of Zurich, Department of Geography. The students were given the task to select a manuscript in review at one of the EGU journals and to write a review. I discussed this review with the student, and find the comments actually quite valuable. Therefore, I post the review here in the hope editor and authors will find them useful to improve the manuscript.

Best regards, Jan Seibert

In the study of Sauquet et al. the vulnerability of current drought management plans (DMPs) in the Rhône-Méditerranée (RM) are evaluated under future climate. To do so water restrictions (WR) from 2005 and 2016 and hydrological data from 1958 to 2013 were analyzed in 106 catchments to derive a framework to reproduce water restriction durations based on low-flow indicators. As the authors write in this framework socio-political factors that can influence the imposition of water restriction are not included. Based on the drought of 2011 a critical threshold of acceptable WR was defined to decide if the DMPs in the future will still be effective. The study aims to assess the effectiveness of current DMPs under climate change to be able to revise the DMPs for the most vulnerable basins. They find out that in temperature-sensitive catchments the water restrictions will increase significantly in the short term and that for this reason there is a need to adapt the DMPs. In the catchments where the precipitation determines the water restriction, they see difficulties to adapt the DMPS as the uncertainties in precipitation is high. They state in the conclusion section several points they did not include in their study but could play an additional role besides the analyses of water restriction duration influenced by temperature and precipitation. These are for example socio-economic system stressors like agricultural practices, population growth, water demand, etc. which also should be considered in the DMPs. In my opinion, it is an important topic to discuss the reliability of current decision-making rules regarding water scarcity in the future when climate changes. The method used in this study can give a good overview of where there is a need to rethink the DMPs. But in my opinion, it would be quite important to take the socio-political factors into account in the framework to reproduce water restrictions. A further improvement would be if the economic system stressors would be included to evaluate the DMPs. Therefore the current method has still a lot to improve, and that's why it is not fully clear what the substantial contribution of this paper is.

Further, I think the description of the method of the hydrological modeling and the framework to reproduce the water restrictions could be more detailed.

➔ Authors agree with this remark and the method needs to be more explained. Water restrictions simulations complement studies on the impact of climate change on water resources availability and on water use needs. Indeed water needs can only be met first if water resources are available and second if water abstractions are allowed. Regulatory rules are pieces of the puzzle that should be examined. Roughly speaking studying water restrictions is a way to identify additional future constraints on water users. The regulatory aspects have never been deeply examined in France, perhaps due to the recent implementation of DMPs. This paper presents a first attempt to simulate water restrictions over a large area in France. This paper aims at promoting the approaches developed in parallel by Brown (named 'Decision Tree Framework") and Prudhomme (named "Scenario neutral approach") and one of the challenges was to define critical thresholds of unacceptable number of days with legally-binding WR for irrigation use. This paper suggests using information provided by insurance (here from a national system of compensation) at the regional scale.

Comments

P1-L22 and P16-L423: The four classes could be explained in P16-L423. The same for Figure 11 and 14, it would be easier to understand if each class would be shortly explained in the figure description.

➔ Climate response surface of WR* legally-binding water restrictions level anomalies ΔWR* is a graphic representation summarizing the sensitivity of ΔWR* to climatic drivers. They all suggest an increase in the occurrence of legally-binding water restrictions when precipitation decreases or when temperature increases. Additional temperature increase and its associated PET increase can compensate for precipitation increase and lead to decrease in ΔWR*. The response surfaces differ by their flatness (e.g. the response surface of Class 3 displays the less contrasted shape).

P2-L54: Is the scenario-neutral approach the same as a bottom-up approach? The authors could use the word "bottom up" as well, as they use it also in the title and it is not used in the rest of the paper. Please clarify difference or similarity.

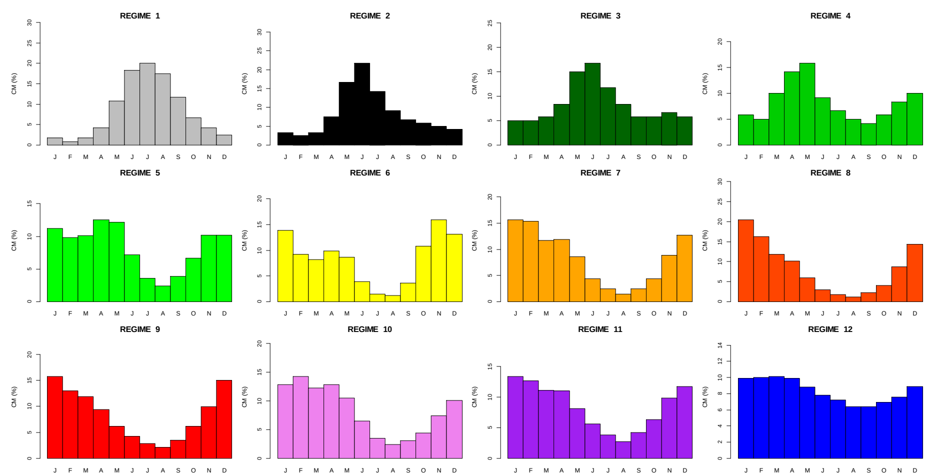
➔ According to Culley et al. (2016), "Bottom-up approaches are an alternative to the top-down procedure […], and have been designed to identify performance thresholds independently from climate models' projections". The approach developed here and based on previous published studies (Prudhomme et al., 2010) does not use downscaled GCMs to describe future climate (scenario-led approaches) but relies on sensitivity-based analyses to a wide range of climate changes, making it scenario-neutral. Ex ante climate projections are considered in the last stages of the procedure to assess the risk of failure. The sentence "specifying relevant critical thresholds is the main task involved in bottom-up approaches" will be added in section 4.1.

P4-L106 to P5-L120: In section "2.3 Hydrological data" it would be good if the 15 regimes suggested by Sauquet et al. (2008) could be shortly explained.

➔ The classification could be given in Appendix.

Sauquet et al. (2008) have defined a classification based on the mean monthly runoff pattern and a map has been published showing the assignment to one class for each basin with drainage area > 50 km².

Groups 1 to 6 are pluvial river flow regimes. The groups mainly differ by the contrast between the maximum and the minimum of monthly streamflow. Nearly uniform flows through most of the year (Group 1) are found where large aquifers moderate flows whereas Group 6 is characterized by very low flow in summer, reflecting the lack of deep groundwater storages in the catchment. Group 7 is representative of Mediterranean river flow regimes where small rivers basins experience hot and dry summers and intense rainy events in autumn. Their runoff pattern therefore exhibits severe low flow in summer and high flow in November. In mountainous areas, uppermost basins display snowmelt-fed regimes (Groups 10, 11 and 12). The lower the outlet is, the lower the contributions of snowmelt to runoff. Groups 8 to 9 are in the transition regime. The seasonal variation of streamflow is affected as much by precipitation timing as by air temperature and topographic influences (on snowpack formation and snowmelt timing). Typically, high flows are observed in spring.



Reference hydrographs representative of the classification of river flow regime for France (after Sauquet et al., 2008)

P5-L121 to P5-L126: In section “2.4 Climate data” Table 2 the RCP2.6, RCP4.5, RCP8.5 scenarios could be explained. And why is Terray and Boé (2013) not listed there as his projections are used in section “5.1 Definition of perturbed climate conditions to build WR response surfaces”?

➔ I am not totally sure to understand the question. RCPs are namely “Representative Concentration Pathways” (van Vuuren et al.: The Representative Concentration Pathways: An Overview. Climatic Change, 109 (1-2), 5-31, https://doi.org/10.1007/s10584-011-0148-z, 2011). The study published by Terray and Boé (2013) is based on global climate simulations. This study was used to define the spectrum of changes in temperature and precipitation. Here regional climate projections available in the DRIAS portal are used.

P6-L163: Is duration *d*, the time used for deciding if water restrictions are imposed? In this case, I do not understand what is meant by 10d-VCNd(T) in p7-L171. In Figure 5 VC3 has a value for every day. Is it calculated from the last three days? Please clarify.

➔ The name of the variable is confusing and it will be changed. We suggest modifying the following paragraph to improve the presentation of the WRL modelling framework: "Water restrictions are decided after consulting drought committees that convene irregularly. The time-step for modelling WRL was chosen to be compatible with the frequency of drought committees estimated from the analysis of the water restriction orders: WRL is thus computed at a regular time step of ten days. VC3(t) is first computed from daily discharge Q(t) every day t, WRL(t) is then deduced by comparing VC3(t) to the four regulatory thresholds and finally a unique representative WR level is assigned to each of the 21 10-day periods defined between the 1st April and the 31st October, as the median of WRL(t) observed or simulated within that 10-day period."

P7-L173: VC3 was selected, as it is the most common single indicators used in DMPs of the RM district. I might have missed something, but this seems not to be the case for the 15 test catchments chosen for the evaluation of the WR modeling framework. It is not clear for me how you can compare these different low-flow monitoring indicators with each other. This should be described clearer.

➔ Indeed the decision that lead to selecting VC3 as monitoring variable is was made considering the 28 DMPs and this modality is not prevalent within the 15 test catchments (Figure 3). We will make it clearer in the final version: "$VC3$ was selected as the monitoring indicator and the regulatory thresholds are low flow quantiles $10d\text{-}VCN3$ based on the minimum 3-day mean discharges extracted by the block minima approach considering the 37 fixed 10-day time-windows as blocks with return periods, as they are the most common single indicators used in the 28 DMPs of the RM district."

P9-L244: Are the 15 catchments used for calibration or only for evaluation? Please clarify.

➔ They were used both for calibration and for evaluation.

P13-L343: It is not clear for me if the perturbation of the climate is based on different climate scenarios as RCP2.6, RCP4.5, RCP8.5 or which exact projection is used. In the reference Terray and Boé, 2013 the authors are using they are also talking of different projections. This needs to be clarified.

➔ The "delta-change" method was used to provide a set of perturbed climates in scenario-neutral approach. Following Prudhomme *et al.* (2010), monthly correction factors ΔP and ΔT were considered:

$$\Delta \mathrm{P}(i) = \mathrm{P}_0 + \mathrm{Ap} \cdot \cos\left[(i - \varphi_{\mathrm{P}}) \cdot \frac{\pi}{6}\right]. \quad (1)$$

$$\Delta \mathrm{T}(i) = \mathrm{T}_0 + \mathrm{A}_{\mathrm{T}} \cdot \cos\left[(i - \varphi_{\mathrm{T}}) \cdot \frac{\pi}{6}\right]. \quad (2)$$

P_0 and $T_0 + A_T$ are respectively the mean annual changes in equations (1) and (2), with i referring to month 1 to 12, φ_P the phase parameter and A_p the semi-amplitude of change (*e.g.* half the difference between highest and lowest values) in equation (1). The parameters P_0, φ_P, T_0 and φ_T of single-phase harmonic function were fixed with respect to the range of changes suggested by Terray and Boé (2013). Finally 45 precipitation scenarios were created using 9 values of P_0 *i.e.* [-20; -13.3; -6.6; 0; 6.6; 13.3; 20; 26.6; 33.3] mm.an^{-1}, by 5 values of Ap *i.e.* [0; 6.6; 13.3; 20; 26.6] mm.season^{-1}, while φ_P parameter is fixed to 1 to consider minimum change in January and maximum change in July. Likewise, 30 temperature scenarios were set up with 6 values of T_0 *i.e.* [0; 1; 2; 3; 4; 5]°C.an^{-1} by 5 values of A_T *i.e.* [-0.5; 0.5; 1.5; 2.5; 3.5]°C.season^{-1} while φ_T is fixed to 2°C to get maximum change in August. These details will be given in the next version.

P19-L513 to P19-L518: The first two sentences of the conclusion would better fit in the introduction.

Minor comments:

P3-L68: Why not saying Rhone-Méditerranée district in southeastern France to be consistent?

P3-L78 to P4-L95: In section "2.1 Study area" a map or a cross-reference to Figure 1 would help to get an overview of the area.

P10-L268: Figure 6 in the figure description: "Table 2" should be "Table 1".

P4-L106: "2.3 Hydrological data" should be in bold.

➔ Changes will be made in that sense.

P4-L90: Why just speaking about the irrigation needs? It might be interesting to get the whole picture for what the water is used.

➔ "The total net water withdrawal is around 6 billion of m^3 in the period 2008-2013 (water abstraction for cooling nuclear plants and hydropower is excluded) with a high proportion of them to support irrigation needs (3.4 billion of m^3, including 2 billion of m^3 for channel conveyance). Only 10% of water abstracted for irrigation originate from groundwater. Total annual abstracted volumes for drinking water and for water for industrial uses represent 1.6 and 1 billion of m^3, respectively."

P4-L109: I do not understand what the authors mean with "Time series including null values or gaps in the data records above 30% of time were disregarded". Does this mean one null value or 30% null values? Please clarify.

➔ "Time series with more than 30% of missing values or more than 30% of zero flows were disregarded."

P16-L426: In Table 5 in the table description please add where this standard deviation Sd is taken from.

➔ Table 5 is now referred in Section 5.2. "This measure is given by the median and the maximum of *Sd* values of the grid (Table 5)."

⇨ The authors would like to thank Jan Seibert and his students for their helpful comments.