

*Review comments on the article submitted to HESS (egusphere-2024-2595) entitled:*

Storyline Analytical Framework for Understanding Future Severe Low-Water Episodes and Their Consequences

by

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This is an interesting and well written article that presents a storyline approach for analyzing future drought conditions in the southern part of the province of Quebec, Canada. The basis for the analysis is the drought event of 2021, for which, in the implemented storyline methodology, similar events (so called 'analogues') are identified in the future, under two Climate Change (CC) scenarios of 2 °C and 3°C degrees average warming. Future climate is simulated using an ensemble of fifty perturbed simulations in which data from a Canadian global circulation model CanESM2 are used to drive a regional climate model CRCM5 for the period 1950-2100 using the RCP8.5 (high emissions) scenario adopted by IPCC. The analogues are identified based on an existing methodology proposed in (van der Wiel et al. 2021), using Standardized Precipitation-Evapotranspiration Index (SPEI) as main indicator of similarity between the 2021 event and the future analogues (historical analogues for the period 1992-2021 have also been identified and subsequently used). The methodology is then extended by using hydrological drought indicators (streamflow-related), which are proposed and calculated for a large number of Southern Quebec watersheds using a hydrological model, driven by bias-corrected outputs of the regional climate model. Main results are presented as maps with spatial distribution of these indicators for current conditions (2021 event) and for conditions coming from the average of the 10 best analogues (most similar to 2021 events), which are then used to assess potential drought impacts on ecosystems and socio-economic activities in the region. The article is suitable for publication in HESS, after addressing the following comments:

1. As the calculation of the hydrological drought indices is central for providing the results of this research, it is necessary to provide some more information about the HYDROTEL hydrological model, and how it was used / set up for this research. Readers unfamiliar with this model need some basic information about the concepts used in it, which then needs to be extended with the following: How many watersheds were actually simulated? (There is a mentioning of 10,000 watersheds and a threshold of 'larger than 50km<sup>2</sup>', but it is not clear how many were finally simulated; all maps with indicator results show streams, but it is not clear how are they related to the simulated watersheds). Which exact outputs of the regional climate model were used? Were these only precipitation and temperature (for which the implemented bias corrections are discussed)? Were the watershed models set up with or without sub-basins? How were inputs and parameters specified (gridded or per sub-basin)? Which were dominant runoff components simulated (snowmelt? direct runoff? subsurface runoff (base flow, which would be important for drought conditions?))? In the 'Limitations' section the authors mention some deficiencies of

the hydrological model used, and that the value of their article is primarily in the methodological framework that has been introduced, and in “producing plausible, physically coherent low-flow indicators” However, the above suggested information, in my view, is still needed for better understanding of the hydrological modelling component of this work.

2. There is certain disconnection between the analytical work carried out to provide the results in terms of hydrological drought indices and the discussion part presented in section 4, especially sections 4.1 and 4.2. These sections mostly present information about drought impacts on ecosystems and socio-economic activities during the 2021 event. There are only some suggestions about how some of the calculated hydrological drought indices could be used to better assess drought impacts, but most of the content in these sections is a description of the impacts from 2021 drought. My suggestion would be to somewhat re-arrange the content in this article and to bring in the description of the 2021 drought in terms of impacts on ecosystems and socioeconomics much earlier (under ‘Introduction’, or under ‘Methodology’ as a separate section, or somehow combined with the section on ‘Stakeholder consultation’). The argument can then be introduced that lack of adequate hydrological drought indices to assess future droughts under CC is an issue that this article addresses (There is even mentioning that the province of Quebec indeed does not have such indicators in line 60). The whole content of calculating these indices would then follow, and the Discussion section can be somewhat extended about the value / potential use of the proposed indicators. The need to move towards the next step, which is developing impact-related drought indicators could then be emphasized in that discussion. This is just a suggestion, and the authors may decide on a different approach to better connect the discussion part with the previous part of the article.

#### Specific comments:

1. Line 5, in the abstract: The statement “This approach allowed for enhanced collaboration with water management experts and other stakeholders to project the possible impacts of climate change on serious water deficits in Quebec.” should be modified or removed. There is no evidence presented in the article that this actually occurred. (This comment is somewhat related to the general comment 2, mentioned above).
2. Please insert somewhere in Section 1 (Introduction) or Section 2 (Methodology) a figure with an overview map of the actual study area, together with geographical features to which you are later on referring (e.g. St. Lawrence river / valley, Ottawa river, Lake of Two Mountains, etc.). This will be very useful for readers unfamiliar with the geography of Quebec.
3. Please make it clear in Section 1 (Introduction) that the focus of this research is hydrological drought (and the indices). When one reads this section, it is not always clear whether meteorological or hydrological drought will be the target of the analysis (later on it becomes clear).
4. Line 60: Please add “and ecosystems” at the end of the sentence “...significantly impact human activities”, to be consistent with the content presented later.
5. Line 85: Please do not use ‘water deficits’, as it adds to the ambiguity regarding what is the focus of the cited study and of this study. The cited study is clearly about precipitation deficits

(meteorological drought) and this study goes further in calculating hydrological drought indices based on streamflow data.

6. Line 95: Please use 'Sect.' or 'Section' consistently.
7. Line 115: The statement "By combining the qualitative data from the questionnaire with the quantitative insights drawn from the storylines, it becomes possible to obtain a more comprehensive understanding of the potential impacts of future severe droughts" should be modified or removed. There is no evidence in the content of the article that such combination was performed. If it is a suggestion that this should be done in the future – the statement should be re-formulated. (This comment is related to the general comment 2, and specific comment 1, mentioned above).
8. Line 125: the sentence starting with "The retrospective analysis..." is not clear. Could you please expand it or re-formulate it? What is meant by 'combining streamflow measurements from various locations'? What was combined and how? Which 'gridded observation data were used for driving HYDROTEL' (again, see general comment 1)?
9. Line 150: The statement "... and, importantly for this work, potential evapotranspiration (PET)" is a bit surprising. Practically all hydrological models use PET as an input, so how can this be a particular feature of HYDROTEL that is important?
10. Line 175: This approach is not entirely clear to me. The SPEI values will be comparable in terms of values, but if they come from two different distributions (from two different climates), how can then they be comparable? Can you please elaborate a bit?
11. Line 225: So, there were 10 best analogues for the historical period *and* 10 best analogues for the future, and the difference between the averages of the two was calculated, right? Please clarify.
12. Lines 270 and 280: Would the results be sensitive to these weights values? Has this been tested? If not, perhaps it should be recommended?
13. Section 3.4 (Limitations). Perhaps it could be recommended to carry out similar analysis for individual basins, and not only for such a large area? This would bring the use of the indicators closer to actual water resources planning and management, in my view...
14. Figure 7. I don't see why this figure is necessary. Many drought impacts have been discussed, and not supported by similar generic information (and figures). Why is this generic view on drought impacts on river systems chosen to be presented? It is a bit of a distraction, in my view. I would suggest to present relevant figures for this particular research (perhaps Figure S2 from the supplementary material?)

Thank you very much for an interesting article.