

We would like to thank the referee for their constructive feedback. We appreciate the time and effort that was put into the review and we hope that our responses prove satisfactory. For clarity, the reviewer's comments are presented in black, with our responses in red.

Best regards,

Gabriel Rondeau-Genesse, on behalf of all authors.

Referee #3

This new version of the text reads well in terms of general issues of climate change, the importance of droughts including the slower processes associated with them, and the construction of scenarios that are able to capture such slower processes.

And yet, I remain really hesitant about the text when it comes to what is mentioned as central to it: the story line ideas. This sentence on page 20, so already well into the Discussion, made me doubt: "In light of the risks posed by climate change and increasingly frequent drought events, the storyline approach offers a valuable framework for understanding, communicating, and preparing for future droughts in collaboration with stakeholders." This may be something that can be accepted as a claim, but the paper does not prove that - as the scenarios were not used to consult with stakeholders.

A reference to Caviedes-Voullième and Shepherd (2023) has been added to this statement, as it aligns with the points made in their paper. Furthermore, both this statement and our manuscript remain consistent with the broader literature on climate storylines already cited, in which stakeholder engagement is typically discussed separately.

However, we have made it clearer in the Introduction that this paper's main goal is to present the climate storyline itself – as in the projection of the 2021 Quebec drought into future climate conditions – and that it aims to provide the foundation for the second phase of the project, which will be the one involving stakeholder engagement. As detailed in another response below, the planning and organisation of these workshops are already well underway.

L.95: The primary objective of this study is to apply a storyline approach to generate plausible, physically coherent projections of the 2021 Quebec drought under future climate conditions. Distinguishing itself from most existing research, the study also incorporates a distributed hydrological model to simulate hydrological conditions during those events at both provincial and local scales. These storylines will form the basis for stakeholder engagement in the project's second phase, designed to foster dialogue on the potential impacts of future water scarcity in southern Quebec and to explore adaptive management strategies.

Perhaps the text wanted to show how story lines could be constructed. That may be a fair goal, but in that case I would need to know how what the text does is different from other scenario-based approaches - which is not discussed. How is a "story line" different from "a certain type of scenario"? I might be missing something here, as I find it really difficult to see what the term "story line" adds to the paper as is. For example, part 3 (Results) does not use the term "story line" at all. I find this a little strange, as I would think that results of a text suggesting that story lines are important would have to show actual story lines in those results.

The term *climate storyline* is well-established in the scientific literature and is referenced multiple times in the IPCC AR6 report. Notably, WG1 Chapter 10 (Box 10.2: *Storylines for Constructing and Communicating Regional Climate Information*) provides a detailed description of the approach. One type of climate storyline, which we use, involves modifying a historical event to simulate how it might unfold under future climate conditions, in a physically coherent manner. This methodology and concept is thus central to our study, even when it was not explicitly named such as in Section 3.2 of the Results.

We have refined the relevant paragraph in the Introduction to further clarify the distinction between multi-model ensemble approaches and storylines:

L.65: *Recently, storyline approaches have begun to be explored in climate change research and may provide a robust framework for projecting the impacts of future extreme events in the absence of clear thresholds, due to their event-based nature (Shepherd et al., 2018; Shepherd, 2019; Sillmann et al., 2021; Matte et al., 2022; Baulenas et al., 2023; Caviedes-Voullième and Shepherd, 2023). Traditional climate change projections evaluate changes in extreme events by examining the potential shifts in the frequency or intensity of events with a specified magnitude or probability of occurrence, such as a 100-year drought. These projections rely on multi-model ensembles, where results from multiple climate models are combined together to provide a robust climate change signal through ensemble percentiles, as well as a likelihood of increase or decrease using the level of agreement between the climate change signal of the individual models. This statistical framework generally does not try to link indicators (e.g. the 100-year drought) directly to specific past events. In contrast, climate storylines can use climate data to construct plausible future scenarios by modifying real historical events, without having to explicitly specify their likelihood. This approach offers a way to simplify complex climate information by projecting how specific events may unfold in the future, thus linking climate information to familiar stakeholders experiences. It also potentially avoids the need to pinpoint specific damage-inducing thresholds by constructing the future scenario based on an event that already caused known damages in the past. Storylines have been applied in both climatological and hydrological research to effectively illustrate future extreme events such as droughts, floods and storms (Schaller et al., 2020; van der Wiel et al., 2021; Chan et al., 2022; Gessner et al., 2022; Chan et al., 2023; Liao et al., 2024).*

In addition, to enhance clarity and consistency, the term *storyline* has been explicitly incorporated throughout the text where relevant, as well as into key sections of the manuscript. Specifically:

- Section 2.5, previously titled *Construction of the analogues*, is now *Construction of the storylines*. The
- Section 3.2, previously titled *The 2021 drought under future climatic conditions*, is now *Storylines of the 2021 drought under future climate conditions*
- The opening of Section 3.2 now also reiterates the methodology as follows:

L.390: *Storylines of the 2021 drought under +2°C and +3°C warming conditions were constructed by modifying the climatological and hydrological indicators computed for the 2021 drought using the analogues found in the ClimEx dataset, as shown in Fig. 3.*

On page 21, we read that "it is essential to note that the primary objective of this study was not to achieve exact modelling of future low flows, but to produce plausible, physically coherent low-flow indicators reminiscent of a recent event to stimulate conversations with stakeholders about the effects of water scarcity

in future climates in southern Quebec." We simply cannot know whether the scenarios were stimulating discussions, as there was no stakeholder discussion.

We read as well that "The constructed scenarios offer valuable insights into potential future conditions and emphasize the importance of preparedness for water shortages." We cannot know this either as the scenarios have not been tested in practices. The authors may find the scenarios insightful, and they are obviously allowed to defend that position, but that does not make what they did a story line approach.

These statements, and others that were similar, have been adjusted to reflect the fact that stakeholder engagement will be performed in the 2nd phase of the project.

L.10: By linking future river conditions to a real event that affected Southern Quebec, storyline approaches have the potential to facilitate discussions on the impacts of climate change on water deficits in the region, particularly in cases where those impact-inducing thresholds are not well understood.

L.470: Storylines can foster dialogue between local actors and climate scientists by making climate data more accessible and relevant for decision-making, particularly for developing effective response measures.

L.495: While stakeholder participation was not carried out in this initial study, we contend that the storyline method supports a more collaborative and informed dialogue between stakeholders, allowing better coordination across sectors such as water management, urban planning, agriculture, and public health by grounding future projections in recent, real-world examples. To further evaluate this potential, the second phase, planned for mid-2025, will investigate how storylines can deliver actionable insights through workshops organized with stakeholders in select watersheds that experienced significant impacts from the 2021 drought

L.515: However, it is essential to note that the primary objective of this study was not to achieve exact modelling of future low flows, but to produce plausible, physically coherent low-flow indicators reminiscent of the 2021 drought, so that they could be used to stimulate conversations with stakeholders about the effects of water scarcity in future climates in southern Quebec. The constructed scenarios can offer valuable insights into potential future conditions and emphasize the importance of preparedness for water shortages.

Perhaps the text focuses on how to create scenarios for droughts, which is perhaps meant with "plausible, physically coherent low-flow indicators reminiscent of a recent event". That focus might be enough, but is less wide ranging than a discussion on the concept of "story lines" in discussion with stakeholders. There are not too many stakeholders in the text...

We hope that the previous answers already contextualize our manuscript with the broader literature on climate storylines, where the development of the storyline is typically treated separately from stakeholder engagement. However, as the planning for the stakeholder workshops is already well underway, the discussion section has been updated to include a more detailed and illustrative example of how our results could be used to construct a local-scale storyline:

L470: Unlike broad, abstract projections like "Future 100-year droughts will be n days longer," which can fail to provide concrete insights into the specifics of what a 100-year drought might entail even in the current climate, storylines offer more actionable and tangible scenarios. While the analysis has primarily aimed to enhance the understanding of future severe drought conditions at the provincial scale, HYDROTEL's distributed nature allows for the tailoring of hydrological indicators to address local-scale issues. In preparation for a

stakeholder workshop planned for the second phase of the project, additional local data is being gathered from nearly 20 participants representing governmental, municipal, industrial, health, environmental, and recreotourism sectors within a watershed north of the St. Lawrence River. By integrating their input with the modeled future events developed in this study, a potential storyline might read as follows: "A drought similar to the one experienced in 2021, but occurring under a +3°C global temperature increase, could persist for up to 26 additional days and lead to a further 30–50% reduction in monthly streamflow. This would have severe environmental and socioeconomic consequences. Streamflow would remain below the environmental flow threshold for over 90 days — more than double the 2021 duration — indicating a potentially catastrophic decline in water quality and biodiversity. Compounding the crisis, between August and October, the nearby city's water demand could consume up to 75% of the river's flow, not accounting for future consumption increases. Recreational tourism, a key economic activity in the region, would also suffer: kayaking restrictions due to insufficient water levels, which lasted 7 days in 2021, could extend up to two months under such extreme conditions." This event-based, context-rich approach allows stakeholders to recognize vulnerabilities by anchoring them to a familiar reference point — the 2021 drought — and projecting plausible future impacts. The city mentioned above was not concerned about water shortages in 2021, but understanding that a future event could last a month longer and leave barely enough water to meet even current needs may prompt proactive adaptation planning, such as bolstering water conservation measures, investing in infrastructure improvements, exploring alternative water sourcing strategies, or developing protocols to avoid conflicts between various users. Similarly, confronting certain water-dependent industries in that watershed with the possibility of future acute water shortages, regardless of existing water withdrawal agreements, could prove eye-opening and reveal potential vulnerabilities in their profitability or operational resilience.