Author Responses to Reviewer #1 Comments

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We would like to thank the reviewer for the time and effort to review our manuscript. The comments provided by the reviewer will undoubtedly improve our manuscript. In the sections that follow, we provide our responses to individual reviewer comments on the manuscript. The responses to individual comments are written in this **color**.

1: Overall assessment

Reviewer comment:

The manuscript reconstructs multi-decadal root-zone soil moisture over Belgium with mHM and characterizes drought events using an SMI-based framework, comparing them with precipitation-based indicators (SPEI-1/3). The central finding—that 2011–2020 is the driest decade since at least 1971—is relevant for Belgian drought monitoring and well aligned with broader European trends.

However, the presentation is currently hard to follow due to (i) too many metrics without a clear hierarchy for ranking drought severity. (ii) Several methodological elements (MPR, KDE→SMI percentiles, Fisher-z, NSE definition, event splitting/merging rules) need one-line clarifications so readers can reproduce and interpret results.

Author response:

We appreciate this constructive assessment. We agree that the manuscript would benefit from clearer guidance on how drought severity is ranked and from concise clarifications of several methodological components. In the revised manuscript, we will (i) explicitly define a hierarchy of drought-severity metrics, (ii) add short clarifying sentences where methods are introduced, and (iii) improve the structure of the Results section to enhance readability and reproducibility.

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2: Comment #1

Reviewer comment:

The title can be read as if only 2011–2020 is analyzed, yet the study reconstructs 1970–2020 and concludes that 2011–2020 is the driest decade of the five. Please revise the title.

Author response:

Thank you for this constructive comment. We will revise the title so that it is clear the study spans the five decades from 1970.

3: Comment #2

Reviewer comment:

Provide a simple, explicit severity ranking protocol. At present the Results toggle between TDM, SMI$\leq \tau$ area, exposure months, peak area, duration, SPEI-1/3, etc., without a decision rule. Readers cannot tell which event is "most severe." Please state a clear hierarchy.

Add a Table listing the top events with: TDM, peak area (%), duration, exceptional-class exposure.

Annotate TDM values directly in Fig. 5 and state in the caption which tie-breaker decided final ranks when two events are similar.

Author response:

We agree that at present the hierarchy of drought classification is not very clear and that can confuse the reader. In the revised manuscript, we will explicitly state that Total Drought Magnitude (TDM) is the primary metric used to rank the droughts as it integrates the spatial extent, duration, and severity into a single measure that enables the comparison of different drought events. We will also establish how the metrics are related.

We will implement these suggestions to improve clarity;

- Add a table listing the top-ranked drought events with TDM, peak affected area, duration, and exceptional-drought exposure;
- Annotate TDM values directly in Figure 5;
- State in the caption how ties or near-equal events are handled (using TDM as the primary ranking criterion).

4: Comment #3

Reviewer comment:

Lines 363-365, is 2016–2017 or 1975–1977 drought bigger? And based on which indicators? Lines 411-414, based on drought persistence, 2011-2020 is the biggest one.

Author response:

This ambiguity arises because 1975–1977 and 2016–2017 are individual drought events. Looking at individual drought events, they are the two biggest droughts. In Lines 411-414, we are referring to the frequency (in months) of droughts in individual decades. So we mean that droughts were most frequent in the 2011-2020 decade. This frequency combines the occurrence of all the droughts in a particular decade. (For 2011-2020 for example, it includes the droughts in 2011, 2016–17, 2018–19, plus all the other smaller droughts). We understand that the language can be confusing to the reader. In the revised manuscript, we will make the language clearer to avoid this confusion and as we propose in comment # 2, we will rank the individual droughts to make the distinction clearer.

5: Comment #4

Reviewer comment:

Lines 365 and 367, when you talk about area percentage, provide the figure reference.

Author response:

Thank you for this suggestion. We will provide the references in the main text so the reader is not lost.

6: Comment #5

Reviewer comment:

Lines 368–372 discuss 2022–2023, but your decadal analysis ends in 2020. Please remove or move to Discussion/SI with an explicit caveat.

Also line 341 says Fig. 5 covers 1970–2023, but the figure appears to show 1970–2020—please make the figure and caption consistent with the text.

Author response:

We agree. We will move the discussion of the 2022–2023 drought to the Discussion, since its inclusion is only to provide additional context. We will also edit Figure 5 accordingly.

7: Comment #6

Reviewer comment:

Add a short description about each subsection at the start of Results. Two–three sentences will prevent readers from getting lost.

Author response:

Thank you for this suggestion. Indeed it is needed to improve readability and we will add the needed contextual information to each subsection.

8: Comment #7

Reviewer comment:

Lines 196-199, explain why resolutions differ.

Author response:

As described in Section 2.2, mHM distinguishes between Level-0 (L0) datasets, which define the static morphological datasets (e.g. land use, soils, DEM), and Level-2 (L2) datasets, which represent the meteorological inputs. Since gridded meteorological inputs are often available at coarser resolutions than morphological data, mHM allows the two datasets to be provided in different resolutions. We have explained this in Lines 158–170. The model harmonizes the data internally using the Multiscale Parameter Regionalization (MPR) technique. With MPR, fields of parameters at a given modelling scale are obtained by upscaling their corresponding estimates at the scale of the input data, based on either the arithmetic mean, the geometric or harmonic means, or the majority operator (Kumar et al., 2013). This upscaling leads to quasi scale-invariant parameters that enable mHM to preserve the spatial variability of state variables, conserve mass balance and reduce overparameterization.

We will make this explanation clear in the manuscript.

9: Comment #8

Reviewer comment:

Define NSE on first use (Results 3.1.2). Give the range and interpretation (≈1 perfect; ≈0 equals mean-flow benchmark; < 0 worse than mean).

Author response:

Thank you for this suggestion. In the revision, we will define NSE and its ranges accordingly.

10: Comment #9

Reviewer comment:

Lines 470-475, restate the minimum overlap area rule used to merge adjacent months into one multi-temporal event. Or how do you define duration. This clarifies whether a brief wet interlude (e.g., March–April 2017) splits or does not split an event.

Author response:

Indeed. We will make this clear in the revision.

11: Comment #10

Reviewer comment:

MPR, what is the full name.

Author response:

MPR is an abbreviation for Multiscale Parameter Regionalization. It appears in line 164 of the manuscript.

12: Comment #11

Reviewer comment:

Terminology clarity. The manuscript uses three different concepts that contain the word "calibration":

- A 5-year warm-up: is it 1965–1969, if yes, why exclude 1970 as a calibration year for drought analysis?
- Excluding 1970 as a calibration year for drought analysis when forming decades (hence using 1971–1980),
- Streamflow parameter calibration (2000–2023) vs validation (1970–1999).

Please clarify these three meanings to avoid confusion.

Author response:

We agree that the current use of the term "calibration" may cause confusion. The warm up period is indeed 1965–1969. The exclusion of 1970 from the drought analysis is not related to model calibration, but to the construction of the SPEI time series. SPEI is based on accumulated water-balance anomalies over preceding months. As a result, January 1970 does not contain valid SPEI-1 values, and January–March 1970 do not contain valid SPEI-3 values. The year 1971 is therefore the first year with complete SPEI values for all months. For this reason, decades are defined starting from 1971 (i.e. 1971–1980). On reflection, referring to 1970 as a calibration year is misleading. We will make the distinction clear in the manuscript.

References

Kumar, Rohini, Luis Samaniego, and Sabine Attinger (2013). "Implications of distributed hydrologic model parameterization on water fluxes at multiple scales and locations". In: *Water Resources Research* 49.1, pp. 360–379.