

1 Response to RC2

We thank Referee 2 for his comments. You will find in this document responses to each comment.

This work investigates the effect of low-frequency variability on low and high groundwater levels extremes measured in the Paris basin. To my understanding, all methods have been applied correctly and lead to results which allow a thorough analysis of the "low-frequency variability induced extremes".

I have some minor questions and remarks.

L11 - At first reading it is not very clear what is meant by "sensitive". Maybe use "low GWLs are stemming/resulting from such low-frequency..".

Indeed, the term "sensitive" is not the best one as high and low GWL may be induced by the low-frequency variability. So, we agree to change the sentence by : "It appears crucial to evaluate whether (and how much) the very high or very low GWLs are resulting from such low-frequency variability (LFV), which was the main objective of the study presented here."

L16 - consisted in

Yes, it will be corrected in the revised manuscript.

L41 - I would say "in the context of global change"

It will be corrected in the revised manuscript.

L42 - for our societies.

It will be corrected in the revised manuscript.

L50 - Hydrological droughts

It will be corrected in the revised manuscript.

L56 - " et rates, that cause low soil moisture content.. " I am not too familiar with this, but here I do not see a difference of gw droughts compared to hydrological droughts.

Both phenomena (hydrological droughts and groundwater droughts) are strongly linked and might even be considered the same, but groundwater droughts should actually be considered as the main driver of hydrological droughts which encompass a wider variety of processes (see for instance Van Loon, 2015). We can add after the sentence "et rates, that cause low soil moisture content.." that groundwater droughts are characterised by decreased and below-normal GWL becoming critical to sustain human activities (agricultural, industrial or domestic uses) but also streamflow that may lead to issues in surface ecosystems.

L65 - according to the type of aquifer and GWL variation.

It will be corrected in the revised manuscript.

L69 - I would say that a water level higher than the soil surface is no groundwater anymore.

Literally yes, but such water comes from the water table and the flood is induced by the rising water table.

L86 - "However, although these indices are useful tools to describe droughts, their principal limit arises from the standardisation allowing for spatial comparison but therefore hindering to keep the variance notion in time series" You are stating important facts here, but especially the second part is difficult to follow. I suggest to split the sentence in 2 and explain better what you mean.

We propose to change it by: "However, although these indices are useful tools to describe droughts, their principal limit arises from the standardisation. This standardisation is useful for spatial comparison, but variance information gets lost. We equate aquifers that exhibit a weak amplitude of variations (i.e., <2m of maximum water table fluctuation) and high amplitude of variations (i.e., 10m of maximum water table fluctuation). This is particularly limiting to understand the emergence of high and low GWL whose amplitude seems highly dependent on the maximum water level fluctuation."

L89 - dependent on

It will be corrected in the revised manuscript.

L107 - .. highlighted, using a composite analysis with Sea Level Pressure (SLP), that the.. (comma insertions)

It will be corrected in the revised manuscript.

L119 - I don't understand. Please rephrase.

Would the sentence rephrase as following be better? "Recently, Baulon et al. (2020) also identified a significant ~17-yr variability in GWL of chalk and limestones aquifers in northern France."

L122 - except the 1975 drought.

It will be corrected in the revised manuscript.

L126 - delete "to", replace "in supporting" with "on"

It will be corrected in the revised manuscript.

L132 - high- and low-frekuensi

It will be corrected in the revised manuscript.

L134 - Why exactly where these 7 and 17 year variabilities chosen? I think this needs explaining. .. consists in evaluating

Because these ~7-yr and ~17-yr variabilities have been shown to be the most important (and statistically significant) low-frequencies in hydroclimatic variables and groundwater levels in northern France and neighbouring countries (Slimani et al., 2009; Massei et al., 2010; Rust et al., 2019; Baulon et al., 2022 (see Fig. 7 with global wavelet spectra)).

140 - Rephrase please

"Second, we propose determining on four well-known historical events the contribution of multi-annual and decadal variabilities in the amplitude of threshold exceedance (ATE) and identify what parameters may control this contribution. In other words, we estimate the percentage of contribution of each low-frequency component in the emergence of the historical event."

L145 - Boreholes were selected from a BRGM database and were required to be undisturbed from human activities. We selected the boreholes by following the three steps below.

It will be corrected in the revised manuscript.

L149 - the removal of pre-selected..

Not the “removal” but “cross-referencing”. We checked in the BRGM databases if there were known anthropogenic influences on the pre-selected boreholes.

L170 - Do you mean sub-monthly?

No, we don't mean sub-monthly. We are not interested by such high-frequency variations, rather mostly in annual variations (and beyond) of GWL that can be particularly significant in aquifers with reactive GWL variations.

L190 - were -> was

It will be corrected in the revised manuscript.

L214 - for that purpose

It will be corrected in the revised manuscript.

L245 - But isn't this also a consequence of the initial amplitude of exceedance?

Yes it is. But here we consider that a low-frequency component influences an extreme level if the component generates the extreme level or if the level is no longer considered as an extreme if the component is subtracted from the GWL signal. In other words:

- if the peak still exceed the threshold when the LFV is subtracted, the peak remains an extreme level, and then we considered that the subtracted component has no influence on extreme emergence.
- if the peak no longer exceed the threshold when the LFV is subtracted, the peak is then no longer considered as an extreme level, and we considered that the subtracted component significantly influences the extreme emergence, since it generates the extreme level.

For better clarity, we propose to introduce the above explanation into this section (3.2.) of the manuscript.

Fig3 - I prefer the term variance, but this is a matter of preference.

We used this term “energy” as it is the term used by Constantine and Percival (2016).

Fig9 - Why not splitting the period exactly in half, doing the analsis for both periods and the complete period 1903-2019?

We presented results as such because the aim was to compare results obtained over the 1976-2019 period with those obtained on the entire time series (i.e., 1903-2019).

P23 - 28 : I wonder how the results are sensitve to the choice of 7/17 and 7&17 year variabilty. I think this has to be discussed or at least commented on.

The ~7-yr and ~17-yr variabilities have been specifically chosen because previous studies showed that these components were the dominant low-frequency variabilities (and statistically significant) in hydroclimatic variables, including in groundwater levels, in northern France and neighbouring countries (e.g., Massei et al., 2010; Rust et al., 2019). This is why we are interested in these frequencies in this study and not others.

L582 – typo

“strengthen”: it will be corrected in the revised manuscript.

L584 - linked to -> resulting from

It will be corrected in the revised manuscript.

L589 - dating back to

It will be corrected in the revised manuscript.

L595 - Which aperiodic behaviour? I don't understand this sentence

Here, we talk about the aperiodic behaviour of low-frequency variabilities. Indeed, they are not periodic (phase and amplitude are not constant over time) even though they look more or less periodic. We propose to correct the sentence as such: “Knowing the dependence of GWE to LFVs, this aperiodic behaviour of LFVs can heavily influence the HL and LL severity in aquifers displaying inertial or combined GWL variation types.”

L601 - largely -> generally

It will be corrected in the revised manuscript.

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