Hydrology and Earth System Sciences Discussions

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Reply on RC1

Luca Guillaumot et al.

Author comment on "Frequency domain water table fluctuations reveal impacts of intense rainfall and vadose zone thickness on groundwater recharge" by Luca Guillaumot et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2022-201-AC1, 2022

Dear reviewer, thank you for your positive feedback. We addressed your different comments below.

Sincerely.

Luca Guillaumot, on behalf of all co-authors.

My only suggestion is that the authors may help readers to see the underlying approach and to understand the significance of the work with a couple of schematic diagrams and some added background explanations. For example, given that the method is heavily reliant on frequency domain analyses, it may be useful to show the power spectrum of recharge at the two sites and to describe it in terms that a general reader can appreciate.

Thank you for this suggestion. We plotted the power spectrum of recharge (see attachment) obtained from soil models and from groundwater levels in Ploemeur and Guidel. First, we observe a similar pattern between the three signals: (1) there is a peak at T = 365 days, (2) recharge amplitude increases with the time period (T). In addition, we observe that the amplitude is higher at high frequency in Guidel compared to Ploemeur. We added this figure along with the previous description to the Supplementary file. However, we think this figure is a bit redundant with Figure 9 showing the transfer function response (recharge/(precip-PET)) in the frequency domain. As suggested, we will give more explanations concerning the frequency domain analyses to help readers.

I would also have appreciated a paragraph to explain the coherence and transfer function results. Can the authors help the average reader to make sense of these so that they can appreciate the results that follow?

Coherence and transfer function are introduced in section 2.6 "How unsaturated zone transforms precipitation into recharge". Then, associated results are presented in section 5.3 "The unsaturated zone and recharge fluxes". Finally, these results are discussed in sections 6.2.1 and 6.3.1.

Section 2.6 will be corrected in the revised manuscript to both describe and « popularize » equation 7 and 8. That is why, we will add some explanations about frequency domain analysis in this part: "These functions allow to infer the role of the soil and more generally of the unsaturated zone." (line 211-212) will be replaced by "These transfer functions *comparing flux coming in vs out of the unsaturated zone allow to infer its role in the recharge dynamics. Switching to the frequency domain offers the additional advantage to visualise how precipitation is converted into recharge at each frequency". In addition, sentences from section 6.2 will move to 2.6 (cf. reviewer 1).*

Following your remark, and because Figure 9 constitutes a main result of our study, we will better explain coherence and transfer function results in the revised manuscript: "On figure 9, the coherence and transfer functions (Eq. 7 and 8) between P − PET fluctuations and RF inform on the efficiency of the transformation of rainfall events into recharge. These functions therefore illustrate the unsaturated zone response to rainfall in frequency domain. In particular the transfer function can be seen as a proxy of rainfall efficiency to generate recharge. From Figure 9, results can be summarised as follows: recharge estimated from soil models and recharge estimated from WTF have similar long-term behavior, recharge estimated from soil models is too sensitive to rainfall at short-term, recharge estimated from WTF is more sensitive to short-term events on the natural site compared to the pumped site" (instead of lines 382-383).

Then, more explanations and discussions are given in section 5.3, 6.2.1 and 6.3.1.

Later, this could help to explain, again at a more intuitive level, how the method filters the effects of pumping and leads to the conclusions regarding the contribution of P-ET to recharge at different frequencies.

Pumping fluctuations are already included as a boundary condition of the model (in x=0) so that the effect of pumping is taken into account (see line 104-107 and 253-254). In addition, we will provide more steps when developing the analytical groundwater model in Appendix 1, so that the pumping boundary condition will appear clearly. We will also mention explicitly this point in section 'Defining the 1D flow model for each field site'.

Finally, I would recommend that the authors provide some thoughts on the applicability of the method to a broader range of sites. Is it, for any reason, limited to fractured rock settings? Does it require a highly instrumented site with a long record? What practical benefits might other researchers and practitioners realize if they apply this approach at their site? All of this is simply aimed at broadening the impact and readership of the work ... the underlying science was a pleasure to read!

Thank you for this comment. The applicability of the method is an important point. We are convinced that the method can be employed to other regions with different aquifer complexity provided that aquifer response can be approximated by a Dupuit equation. It would be very interesting to test it in karstic system where heterogeneity is more pronounced and Dupuit equation more critical. Due to the fixed 1D model structure, a critical aspect is that the method will be not relevant for boreholes located in areas where the water table pattern changes across seasons (see line 460-470).

The method requires long-term water table records and a first guess of weekly or monthly recharge rates which can be roughly estimated from precipitation and temperature data (line 493-497). In order to inverse recharge it is more suitable to use high frequency water table records (daily). Finally, benefits are twice : estimating aquifer-scale characteristic time from a single point and estimating recharge (then its relationship with other variables as we did it by comparing recharge to P-PET on two sites).

Following your comment, the last part of the abstract will be revised as follows in the revised manuscript: "Overall, this approach contributes to better assess recharge and enable to improve the representation of groundwater systems within hydrological models. In spite of the heterogeneous nature of aquifers, parameters controlling WTF can be inferred from WTF time series making confident that the method can be deployed in *different geological contexts where long-term water table records are available".*

Moreover, the last sentence of the conclusion will be revised as follows : "This method could be applied in several parts of the world where GW levels time series are available over long time scales. In this study, the method is applied in crystalline contexts that display fractured aquifers, highly heterogeneous which is challenging. Thus, similar approaches could be deployed in different geological contexts. In particular it could be very interesting to test it in karstic aquifers. This method constitutes a useful alternative to study GW flows and recharge processes and their sensitivity to imposed boundary conditions, namely, precipitations and water use."

Please also note the supplement to this comment:
https://hess.copernicus.org/preprints/hess-2022-201/hess-2022-201-AC1-supplement.pdf