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Reply on CC1

Shouchuan Zhang et al.

Author comment on "The origin of hydrological responses following earthquakes in a confined aquifer: insight from water level, flow rate, and temperature observations" by Shouchuan Zhang et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2022-326-AC3, 2022

Dear Joshua Leusink,

Thanks for the detail and helpful comments, we have read it carefully and made necessary. This reply is following your point by point comments: And the detial response would be added in the revised manuscript soon.

General comments

1. Single well

To start with issue (1): in the research only one single well was used to retrieve the data from. The other deeper well is not used in the research as an input location for the main research results and data acquisition. Therefore, one could argue how significantly and plausible the results represent the area and the processes taking place in the aquifers. Using a larger number of wells will cover the possible local bias in the results. Therefore, the regional effect can be described better (Mohr et al. 2019, Cox et al. 2012, Hosono et al. 2019). Another possibility could be to use discharge data coming from springs in the area, this was also used in the research of Manga and Rowland (2009). Although the discharge in a spring could be different from the increased discharge in a well, this extra data source could still enhance the significance of the dataset. Of course, temperature data could be a bit ambiguous, I would not advice to use this spring temperature.

Response: Firstly, it would of course be good that if we could have more data and wells involved in the study. However, only two wells (Dazhai well and Dazhai deep well) could be collected in this small basin. And Dazhai well and Dazhai deep well are monitored for different items. Dazhai well is used to conducted hydrogeological monitoring, including water level, water temperature and flow rates. Dazhai deep well is used to conduct geophysical monitoring, which is equipped with clinometer, seismometer, magnetometer, and strain gauge. Thus, only Dazhai well has continously monitoring hydrological data and can be used to analyze the hydrogeological response to earthquakes.

The hot springs and saline springs are mainly distributed along the faults in the northern part of Lanping—Simao basin, while few springs occur in the southern part of this basin. However, there is no continuously measurement of these springs. In addition, Dazhai well is located in the Yixiangba sub-basin which belongs to the Lanping-Siamo

basin. In this secondary hydrogeological units, there is no hot spring. Thus, it is with regret that no long-term monitoring data from other springs nearby Dazhai well can be used to analyze the hydrogeological coseismic response.

- *Research focus and motivation*

Following with issue (2): in the section 'Geological setting and data sources', which could be acknowledged as the "Site description", the authors explain about the geological setting of the whole basin, to my opinion this also influences the resulting hydrological response in the aquifer of the well. However, in the conclusion and the other parts of the research, this broader perspective has not been touched upon. Therefore, it would be recommended to either point out that only the Dazhai well and the aquifers it is directly connected to are of importance, or one should broaden the perspective to the whole (or part of the) basin. I would suggest to either make clear that this research only has investigated the Dazhai well (Most straight forward). Or discuss in the discussion section about the representability of this single well to the whole area/aquifer. This can be done with extra boreholes to gain extra lithostratigraphic knowledge of the area or by using the already provided information about the present aquifers.

Response: Thanks for your helpful suggestion. The Dazhai well-aquifer system is the most important research object in this study. We only focus on the coseismic hydrological response of Dazhai well-aquifer system instead of the whole basin or sub-basin. We have adjusted the paragraph structure of Chapter 2 and added the secondary title. The geological setting of the whole basin is considered as the background knowledge and prerequisite of coseismic hydrogeological responses.

- *Statistical analysis*

Following with issue (3): in the research the statistical analysis is not always consistent and is sometimes not present. The authors make use of three models, the Hsieh model, Marquardt-Levenberg algorithm and the end-member mixing model. They provided clear and good overview figures (figure 5: Hseih's model, figure 7: Marquardt-Levenberg algorithm and figure 8: End-member mixing model) of the obtained results and the model outputs. However, without any significance test or model and observation tests it doesn't make sense what the figures represent. For me it is hard to discuss whether the observations are well described by the model or not. The figures can give a wrong visualisation of the data. For the Marquardt-Levenberg algorithm this has already been provided in the supplements. Suggested would be, to provide a more or less equal type of statistical analysis that already have been done for the Marquardt-Levenberg algorithm (in supplement S5). Provide in this test how well the model represents the observations.

Response: For the Hsieh's model, the phase shift and tidal factor inferred from water level by Baytap-G have calculation errors. Actually, the significance test of results has been calculated in the Hsieh's model. The error bars in Figure 5 represent the 95% confidence interval which indicates that there is 95% probability of occurrence for calculation results (phase shift and tidal factor) within the range of confidence interval.

The most essential difference between Marquardt-Levenberg algorithm and end-member mixing model is that Marquardt-Levenberg algorithm is used to fit to the observed values, which can be conducted for statistical analysis between the fitted values and monitored values, while the results of end-member mixing model is not from the fitting value of monitoring values but from the calculation results of equation 18 and 19.

Thus, it is hard to conduct the statistical analysis for calculation results.

- *Research question(s) and hypotheses*

Concluding with issue (4): The paper does not indicate what the research question is. In the introduction it stated what the investigation will be about, but it does not mention what question(s) will be answered. Based on the introduction and abstract it becomes clear what the aim of the research is. Due to the lack of this research question, it is hard to check whether the research question(s) are answered within the research and conclusion.

Advised is to provide one or more research questions. Preferably with hypothesis to strengthen the research. The goal of a hypothesis is that a provided research question is hypothetically answered and could be either rejected, adjusted, or approved based on the discussion of the results.

Response: Thanks for your helpful suggestion. We have revised the manuscript in Line 12~14 and Line 40~43, and indicated research question in the abstract and introduction section, as follow:

"In this study, we quantitatively analyze the mechanism of coseismic response in water level and flow rate from an artesian well in southwestern China before and after multiple earthquakes, and investigate the origin of the earthquake-induced hydrological response based on the monitoring data of water temperature."

"Based on the coseismic response of water levels, flow rate and water temperature responses to several earthquakes in an artesian well (Dazhai well), this study aims to: (1) quantitatively evaluate the mechanism of anomalous hydrological changes. (2) investigate the origin of the earthquake-induced hydrological response based on water temperature monitoring data."

Minor comments:

- Research paper structure: Paper misses a clear Methodology and results section. In the manuscript I can find where these sections are, but it is not clear at first sight. Moreover, it seems that in the result section and even the discussion new methods are introduced. Like the end-member mixing model (line 385). This model is an important model that is needed to find the answer to the research question. Consider moving this to a Methodology section.

Response: Disagree. In this study, several methods are used to analyze the hydrological coseismic phenomena and reveal the mechanisms of coseismic hydrological response, including the estimation of jog volume and fluid pressure change, tidal analysis, Okada model, the estimation of volume of aquifer excess recharge, and end-member mixing model. Different methods correspond to different mechanisms. If these methods are introduced and summarized in the methodology chapter, it may confuse the readers to find exactly which method corresponds to each mechanism. Thus, the methodology section is not added in the revised manuscript. To make readers to find methods clearly corresponding to the different mechanisms, we have added the flow chart in the discussion section of the revision.

In order to make the content of each chapter in the manuscript more clearly, we have revised the titles of different chapters in manuscript. Chapter 4 is entitled "Results", and the secondary titles of this chapter are "Changes in horizontal hydraulic diffusivity" and

"Changes in vertical permeability", respectively.

- Site description: There should have been a site description instead of what is now mentioned as the geological setting of the area. In the section 5.2 line 390-391 there is also new site descriptive information which needs to be in the site description.

Response: Chapter 2 is split into three separated secondary section which are entitled "Regional Geological Setting" "Information of Monitoring Well" and "Data Collection", respectively. The section 5.2 line 390-391 of previous manuscript is moved into section 2.1 Regional Geological Setting in the revised manuscript.

- Chapter 2, consider splitting these in a 'Site description' and a separate 'Methodology and data sources' section. Where in the second section the beforementioned methodology is included.

Response: We have split Chapter 2 into three different secondary sections, including Regional Geological Setting, Information of Monitoring Well, and Data Collection. For the methodology, we have added the flow chart of methods in the discussion section. We believe it is the most appropriate way to make reader understand the different methods corresponding to the mechanisms clearly.

- One could decide to combine the result & discussion (chapter 3-5).

Response: Disagree. The content of Chapter 3 describes the observed phenomena of water level and temperature coseismic changes, which is not the model calculation results. It is not appropriate to be merged into the section of the result & discussion. Thus, this section is still a separated chapter.

In the revised manuscript, we revised chapter titles and added secondary titles. The content of Chapter 4 is the results of tidal analysis which estimate the change of vertical and horizontal permeability caused by earthquakes. In Chapter 5, we reveal the coseismic mechanisms of water level and temperature from the static and dynamic strain, and the end-member mixing model. The new title of Chapter 3, 4 and 5 are "Observation of Coseismic Water-level and Temperature Changes", "Results", and "Discussion", respectively. The secondary titles of Chapter 4 are "Changes in horizontal hydraulic diffusivity" and "Changes in vertical permeability". The secondary titles of Chapter 5 are "Mechanisms of Water-level Coseismic Responses", and "Possible Mechanism of Water Temperature Coseismic Change", respectively.

- Lack of analysis to the magnitude of the proposed mechanisms. There have been issued several mechanisms influencing the hydrological responses, however these only have been appointed to be present. The mechanisms have not been analyzed on their magnitude, which may make a difference in the way the conclusions are drawn, it will probably change the emphasise on a certain mechanism. Though this may be out of scope for this research.

Response: There are three mainly mechanisms in this study: static strain, dynamic strain and end-member mixing model.

The scale of static and dynamic strain effect may not be quantitatively calculated. The

earthquake-induced coseismic static strain is produced by the slip of ruptured fault. The effect of static strain on the change of aquifer parameters only occurs near the epicenter. Dynamic strain is induced by the propagation of seismic wave. The effect of dynamic strain far outweighs that of static strain.

The end-member mixing model indicates that earthquake-induced water temperature anomalies is attributed to the mixing of groundwater with different temperature. The permeability change calculated by tidal analysis cause the mixing of groundwater from different aquifers. For tidal analysis, the distance from the center of the well to the place where the drawdown decays to 5% of its maximum is the most sensitive region that represents the influence scale of the tidal analysis (Xue et al., 2013; Allegre et al., 2016; Zhang et al., 2019). Thus, the scale of end-mixing model is a few dozen meters around well.

- The text is not always concise in the use of grammar and spelling, the conclusion for example first starts in the past tense and then switches to the present simple.

Response: We have corrected the wrong tense of manuscript, especially in the abstract and conclusion section, and revised the sentences with the present tense. The revised part is highlight in yellow.

In line comments

- 98, where is this 4 m coming from? Please provide elevation level of the well to check based on values in line 81 whether 4m is correctly calcula. ted.

Response: The elevation level of Dazhai well is about 1471m. the groundwater head of the shallow sandstone aquifer is about 1475m. Without the discharge port, the hydraulic head would be 4 meters above the surface. We have added the information of elevation level of the well in Line 82~83 of revised manuscript.

- Caption Figure 3 & 4, I suggest to change 'times' to 'events'.

Response: Corrected.

- Line 136 typo: Mk -> mK.

Response: Corrected.

- 196 there is for example mentioned something about a 95% confidence interval, however it is not clear to me which values are within this 95% interval. Do you mean that the errors are within a 95% interval or the changes in phase shift and tidal factor? This could either be a typo or an actual research failure. I would recommend providing this statistical test as a supplement.

Response: According to the calculation results from Baytap-G, the phase shift and tidal factor inferred from water level have calculation errors. The error bars represent the 95% confidence interval which indicates that there is 95% probability of occurrence for

calculation results (phase shift and tidal factor) within the range of confidence interval.

- 199 Incomplete data representation, only for EQ 4, 6, 7, 11 the changes are discussed, what are the changes for the other earthquakes?

Response: We have added the calculation results in Line 233~234 of revised manuscript. The rate of change in tidal factors changes following EQ 1, 8 and 12. The changes are 50%, 12.5%, and 25% following EQ1, EQ8, and EQ12, respectively.

- 206 & 207, Typo? => there is stated that EQ11 and EQ12 have a phase shift smaller than -10 degree, however according to the table this value is larger than -10 degree.

Response: It is a typo. The value of phase shift change in Table 2 means the difference between the phase shift after and before earthquakes. The phase shift following EQ 11 and EQ12 are > -10°. We have revised it in Line 240~243 of revised manuscript.

- 210, typo in maybe it should be 'may be'.

Response: Corrected.

- Figure 5: What do the red and blue dotted lines indicate? Please add this to the legend of the figure.

Response: *H* is the amplitude of the fluctuating pressure head in the elastic aquifer responding to the tidal stress. Due to the influence of seismic activities, the value of *H* is change before and after earthquake. The blue and red lines is the theoretical model (equation 2 and 3) with different *H*. We have added the legend of Figure 6 in the revised manuscript.

- 241, 321, 444 preexisting or pre-existing, please be constant in its spelling.

Response: We have revised these spelling problems with a uniform format.

- 244 word-choice, dilate -> dilation.

Response: We have revised it.

- 245-247 & table 2, Here indicated that for the next analysis the values in table two will be used, however EQ1 and EQ8 are indicated not to be used but are still in the table. I suggest discarding them from the table.

Response: The earthquakes in Table 2 are the result of earthquakes classification in Table 1, because we consider earthquakes that occurred within three months of each other as a single earthquake to reduce post-seismic effects on the aquifer properties. If

the EQ1 and EQ8 are discard from Table 2, the classification results are inaccurate. In addition, although the large distant earthquake EQ1 and EQ8 with the lower value of static strain are not analyzed in the static strain section, both of them are used to analyze the mechanisms of dynamic strain. Thus, EQ1 and EQ8 in Table 2 cannot be discarded in Table 2.

- 385-389 Consider moving this part to the methodology section.

Response: Disagree, we have responded it in our previous response.

- 390-392 Info could be added the Site description, this is new information about the area.

Response: We have moved the climate information into section 2.1 Regional Geological Setting of revised manuscript.

- Conclusion -> Inconsistent in the used tense, either use past tense or present tense.

Response: We have corrected the wrong tense of the conclusion section, and revised the sentences with the present tense.

- 445 add "the" before hydrogeological setting.

Response: We have added it.

- 445 either it is: from 'the deeper' aquifer or from deep 'aquifers'.

Response: It should be "from the deeper aquifer". We have revised it.

Reference:

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