Review of the manuscript hess-2021-584 "Delineation of discrete conduit networks in karst aquifers via combined analysis of tracer tests and geophysical data" by Bodin J, Porel G, Nauleau B, Pasquet D

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1 General comments

This manuscript is devoted to the development of a procedure based on the analysis of tracer tests and seismic data to map the conduit network of a karst aquifer.

The work is interesting. From the scientific point of view, the description of the BTC fitting procedure should be improved, because it is not thorough, sometimes is not clear and rigorous.

The manuscript is well organized and well written. However, some sentences could be misleading and some terminology is not fully appropriate.

I think that the overall quality is sufficient and the manuscript could be published, after a moderate to major revision.

2 Specific comments

1. Lines 38 & 39. The statement "the amplitude of the geophysical anomalies associated with karst conduits highly depends on their size and depth" is quite generic. The same sentence could be used for the application of geophysical methods to any geological environment, e.g., one could write that "the amplitude of the geophysical anomalies associated with sedimentary structures in alluvial aquifers highly depends on their size (thickness and lateral extension) and depth". Specific problems related with the application of geophysical methods to map karst structures (a mixture of "linear" conduits and "volumetric" cavities) is given in a more appropriate way at lines 319ff.

2. Line 44. I would avoid sentences like "it has been increasingly agreed that geophysical imaging methods are not silver bullets". This is an example of generic statements which do not provide any scientific, rigorous message.

3. Lines 48 & 49. May be, I do not properly understand the sentence "To the authors' knowledge, the only previous study to map karst conduit networks based on geophysical data is that of Vuilleumier et al. (2013)", but it sounds strange to me. In fact, the manuscript lists several papers which deal with the problem of mapping conduit networks in karst areas with geophysical methods. Moreover, Chalikakis et al. (2011) is cited as a review paper on this topic. A fast check with on-line search engines, like Google Scholar, provides some other papers which show the use of geophysical data to map karst features (e.g., `DOI:10.1016/j.crte.2009.08.005` and `DOI:10.1007/s10064-004-0247-4`).

4. There is some confusion in the definition and application of the inverse problem.

   (a) Lines 108. Which weight is used in the definition of PHI?

   (b) Lines 110, 11 & 124. The work by Vilfredo Pareto is associated to multi-objective optimization. This paper does not consider such an approach. Moreover, "Pareto curve" is used either to indicate the Pareto set, when dealing with two objective functions, or to denote cumulative curves in statistical software packages.

   (c) Lines 117 to 120. Regularization is obviously useful to design stable methods of solution, but it would be important to give more details about the parameters used and to discuss the sensitivity of fitted values with respect to such parameters. Also it would be important to discuss the characteristics of PHI (local minima, flat behavior around the minimum, etc.).

   (d) The choice of N^* is somehow arbitrary. The criteria given in the text are not strict. From the plots in the upper part of Figure 2, I would consider acceptable $N^* = 2$ for MFIT-2RNE, because adding another channel does not significantly improve the fit. I think it would be necessary to consider error measurements

to choose the value of N^*. For instance, one could fix a threshold for PHI, say PHI^*, physically congruent with the expected uncertainty in the data, so that N^* could be chosen as the smallest value of N such that $PHI(N) < PHI^*$.

(e) Line 120, figure 2. Is PHI a dimensionless quantity?

(f) Line 123. The squared errors are weighted (see specific comment #4a above), aren't they?

(g) Line 335. What is meant by "inversion methods based on a discrete approach to flow and/or transport paths"? Details should be given.

5. Some details about the data are missing or not precise.

(a) Information about diameter, casing and screened intervals of the boreholes are missing.

(b) The depth below the ground surface of the three lithostratigraphic units where karst feature are dominant is not given in a precise way in this manuscript and in the referenced papers. I list the data in Table 1. There is a lot of confusion, which must be fixed.

(c) The papers to which the reader is referred for details about the seismic reflection survey are rather disappointing, as they are affected by a certain degree of self-plagiarism, in the sense that some paragraphs and figures are "copy-and-pasted" among the papers. In my opinion, the most interesting for the content of this manuscript is Mari and Porel (2008). My suggestion is to accompany the citation in the text with a short description of the differences between the four cited papers.

(d) The processing sequence for reflection seismic data does not include migration. Are the reflectors poorly inclined?

Paper	shallow unit	intermediate unit	deep unit
This manuscript	50	90	115
Mari and Porel (2008)	50	88	115
Mari et al. (2009)	35 to 40	85 to 87	110 to 115
Mari and Porel (2018)	35	88	110
Mari et al. (2020)	35	88	110

Table 1: Depths (in meters b.g.l.) of the lithostratigraphic units hosting karst features.

3 Technical comments

1. Line 43. Expression "applicable to very small and deep karst conduits" is misleading and should be rephrased.
2. Line 49. "This" should be substituted with "that".
3. Line 69. I have never seen the use of the expression "tracer-labeled solution". "Tracer" is enough.
4. Lines 71 & 72. Remark "with a much shorter duration of the injection signal than the mean tracer transit time" could be expanded and specified. Is this remark given to support the approximation of a pulse injection? If so, it should be explicitly stated.
5. Line 80. "Heavy" should be substituted with "long".
6. Lines 132 & 133. Expression "geophysical field" is not precise. The gravity field, the magnetic field, the geothermal field are "geophysical fields".
7. Equation (1). The explanation of this equation is rather cumbersome, but at the very end the concept is rather simple. I think it can be described in a better way. The symbol "$\forall$" can be erased.
8. Line 174. Expression "as shown in Fig. 1" is misleading. In fact it shows disconnected paths, whereas this sentence talks about "paths... not supposed to be fully disconnected".
9. Lines 245 & 475. "2021" should be corrected with "2018".
10. Line 248. Add the years of publication after "Mari et al.".
11. Line 265. Is "opposite" the right word? May be, "perpendicular"?
12. Line 267. "The overall velocity range based on the borehole flowmeter surveys was 0 - 3.5 m/min" should be substituted, possibly as "The maximum velocity measured during the borehole flowmeter surveys was 3.5 m/min".

13. Line 272. Add “in” after “is shown”.

14. Line 273. Expression “with contrast to synthetic studies” can be erased.

15. Lines 288 to 291. The sentences “The N130-140 direction... Häuselmann et al., 1999)” should be moved in the text.

16. Line 291. Häuselmann et al. (1999) is missing in the reference list, isn’t it?

17. Line 292. The sentence should be rephrased, because, in the present version, “its” refers to “computed network”, whereas I assume it refers to the real karst network.

18. Lines 323 & 330. The sentence “The source code... the interested user” can be erased, as it merely repeats what is clearly and extensively written in the specific section.

19. Appendix A. I think that the table is not relevant. It would be much more informative a figure with two histograms or box plots showing the distribution of N^* for the two models. Also, it would be interesting to see the trend of $PHI(N)$ for each case.

20. Line 405. Add “`DOI:10.5441/002/edbt.2017.37`”.

21. Line 441. “Springer” should be corrected.

22. Line 490. “Springer” should be added before “Netherlands”.

23. Lines 502 & 503. “In 2015 International Conference on Industrial Engineering and Systems Management (IESM)” should be added before “edited”. Number of pages (663–669) and DOI (`10.1109/IESM.2015.7380229`) should be added.