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Editor: Hydrology and Earth System Sciences

Dear Editor:

I wish to submit the following revised manuscript, 'An extended trajectory mechanics approach for calculating the path of a pressure transient: Traveltime tomography' for possible publication in *Hydrology and Earth System Sciences*. In response to the editor's and reviewers comments the following changes were made:

Editor:

(1) We changed the title 'Hydraulic tomographic imaging' changed to 'Traveltime tomography'.

(2) The dimensions are provided with each new variable.

(3) Put in the word 'subsurface' on Line 10 of page 1.

(4) On page 5, around line 25 we define the scalar K in relation to the full tensor bold K.

(5) Make the various small suggested changes.

Referee 1:

(1) If someone is interested in a semi-analytic approach for imaging flow properties between boreholes then the method will be of interest to them. Such blanket statements are typical of this reviewer who was not constructive.

(2) Complete approach to inverse modeling?

a. We now compute resolution and model parameter errors, as plotted in Figures 7 and 17. We have extensive experience in model assessment in hydrology (Vasco et al. 1997), and introduced the concept of model resolution into the hydrological

community.

b. The imaging algorithm does recover the two high permeability zones. Furthermore, the application to the Widen site does produce an image that is similar to joint inversion plotted in Figure 15. As noted by Referee 2, the solution also agrees with other studies of the area.

c. This approach can be part of an integrated imaging and inversion method. The reviewer is simply wrong when they say it cannot be done. However, that was not the purpose of this paper which was to illustrate the technique and compare it to a conventional algorithm in a relatively simple situation. More complicated studies can be the topic of future papers.

d. The geometry was based upon a readily available data set from a region that has been analyzed by several investigators. The approach is general and can be applied in other settings. For example, as noted in the paper and illustrated in Vasco et al. (2000), a form of pressure travel time tomography can be applied to constant rate pumping data by using the time derivative of the transient pressure changes.

e. This is an iterative solution to the non-linear problem. We are not linearizing the problem except to take a step in our solution algorithm.

f. The Referee does not specify or define what is an acceptable inverse modeling strategy. This comment is not constructive. Regardless, we do conduct a model assessment on uncertainty quantification, if that is what the Referee is referring to.

(3) a. The core data were not extensive and, as noted in the paper, supported the general variation show in Figures 14 and 15, with higher permeabilities at shallow depths and decreasing with depth.

b. The field case is generally layered and this motivated the test case. Crosswell experiments are most accurate in quasi-two-dimensional situations. In highly three-dimensional settings there can be significant out of plane flow and transport, invalidating the approach and making a unique interpretation impossible. One is ill-advised to rely on a handful of crosswell experiments in a medium with significant out of plane heterogeneity.

c. See the discussion above.

d. 'General porous medium' means any medium that can be modeled using a reservoir simulator. For a fully 3D medium we would not use a crosswell geometry. Rather, we might try a fully 3D experiment with numerous multi-level samplers or even using multiple geophysical data sets, including geodetic data. The technique described in this paper can be used in such situations, as it is valid in a general porous medium.

e. We dispute the Referee's negative conclusion.

Referee 2:

General-

(1) We now include a brief overview at the beginning of the Methodology section, along with a schematic figure outlining the approach.

(2) In the Conclusions on page 15, Line 15, we note that the new approach only requires a forward simulation for each experiment rather then a solution of both the adjoint equation and the forward problem as is required by adjoint methods for sensitivity calculations.

Specific comments-

(1) On page 13, line 33, we note the high permeability layer.

(2) P7L30, Removed the second mention of conducting a reservoir simulation. Now page 8, line 5.

(3) P9L9. Limiting the angles may be beneficial if there are experimental issues with source receiver pairs at high angles, as in some seismic tomography work.

(4) P10L13. We now use 10 iterations for both algorithms. The number of iterations depends upon the convergence rate of each approach. This will generally depend upon how close the starting model is to the final model and the non-linearity of the inverse problem, as well as the errors on the data. Due to the modeling errors the eikonal iterations never reduce the actual reservoir simulator errors to small values, even though the eikonal traveltime errors get quite small. We stop iterating when the errors no longer decrease with successive iterations.

(5) P10L23. Edited this sentence, eliminating the unnecessary complexity. Now on page 11, Line 15.

(6) P13L25. Merged the Discussion section with the Conclusions. Now Page 14, Line 15.

(7) P14L15. If the modeling is done correctly the approach should work well in fractured media. However, I have some doubts that a continuum model will handle the fractures with sufficient accuracy.

(8) P14L21. Corrected 'mechanicss' to 'mechanics'.

(9) Fig. 1. Both are used as sources and receivers.

(10) Fig. 7. Removed the reference to contour lines. They were in a previous version of this figure.

(11) Fig. 11. Added these references to those mentioned in the discussion of this figure (now Figure 12).

(12) Yes. We have included some discussion on page 14, line 15. Because there is not much redundency in the experiment, deleting the source at position 5 may have impacted the solution, leading the large negative anomally at the right side of the model.

The reviewers have helps us to improve the paper by suggesting a figure that outlines the approach (Figure 1) and by pointing out the need for a model assessment. Though the tone of Reviewer 1 was excessively negative and most of the comments were not constructive, they did motivate us to calculate the resolution and uncertainty for both the synthetic and field cases. If there are any problems with the submission, please contact me via the above e-mail or telephone numbers. Thank you for your consideration.

Sincerely,

Don Vasco

Editor: Hydrology and Earth System Sciences