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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Halon-1301 — further evidence of its performance as an age tracer in New Zealand groundwater" *by* Monique Beyer et al.

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Dear Axel, Many thanks for your valuable feedback on our manuscript. Below, we detail our responses to your comments. We intend to closely follow your suggestions.

Comments from A. Suckow (Referee) axel.suckow@csiro.au Received and published: 28 May 2017 General Comments: This manuscript massively extents the data set for Halon 1301 in New Zealand (>300 measurements) compared to the 2015 paper in HESS of the same authors, and compares its usability with tritium, SF6 and the CFCs (CFC-11, CFC-12, CFC-113). The analysis uses a lumped parameter (LPM) approach – the exponential piston flow model (EPM) with an evaluation of mean res-

idence time (MRT) and volume ratio (E/PM) for this model – to assess agreement in "groundwater age" as inferred by the different tracers. It is very well presented and besides the obvious demonstration of the usefulness of H1301 the article also shows some valuable new approaches in demonstrating and quantifying agreement in lumped parameter model results. It is clearly worth publishing with minor revisions in HESS. Specific Comments: Although using only one specific shape of an age distribution (the EPM), the paper does a good job in evaluating comparability of LPM results for different tracers for the same water sample as "agreement in inferred age". Of special value here is the 2d-plot of the E/PM parameter versus the MRT for different tracers if the model results are in the 1-sigma range of the measurement. This is a very useful way to display these results that I have not seen before. The developed metric, however, is worth discussing in more detail. While I completely agree not to use MRT only, I have a problem with the attempted metric. No overlap of the two data clouds in Fig. 4 simply means that the two tracers give differing results which cannot be brought into a 1-sigma agreement with any parameter combination. So what is the meaning of the "Euclidian distance between two data clouds"? And what is the "% difference in MRT and mixing parameter inferred with two tracers"? Is the percentage (distance divided by what?) taken from the MRT and mixing parameter of the two nearest points or from the whole axis? For example, if the nearest two point in figure 4 left have 20 and 30 years MRT, is the percentage in MRT then (30-20)/(20)=50%? Or is it (30-20)/100=10%?

–> Thanks for pointing this out. We agree that more discussion around the developed metric would be great. We intend to include your comment re "No overlap of the inferred LPM parameter clouds implies that the two tracers give differing results which cannot be brought into a 1-sigma agreement with any parameter combination." –> We also intend to include an equation for the metric '% difference in MRT' to clarify its definition.

Most of the following paper uses a 10% criterion on this distance as "agreement" (Fig. 6, 7, 9, 11, 12) which is misleading, because any percentage >0 means the two results actually disagree. Perhaps a better way for quantifying agreement or disagreement

would be to use a 1-sigma and a 2-sigma evaluation. Overlap of the clouds generated with 1 sigma would be good agreement, overlap of clouds with 2 sigma still agreement with a certain smaller probability. No overlap of data clouds generated with 3 sigma would be clear disagreement. In case of disagreement (e.g. 6% of the sites with SF6 and 3H available) an evaluation of the uncertainty in recharge temperature, recharge altitude and excess air may be valuable – perhaps this would bring the results into agreement within the 1 sigma uncertainty of these parameters? Similar for H1301, since its dependency on temperature, altitude and excess air is different than for SF6.

–> Thanks for your suggestions. We generally agree that it is a good idea to use multiple distance measure levels to assess agreement/disagreement. As this is one of the first attempts to use that type of approach, we decided to use 1 sigma uncertainty for the following reason. As we illustrate, most inferred LPM parameter clouds are already relatively large when using the 1 sigma criterion implying large uncertainties in inferred age parameters (this is not surprising as we only use 1 measurement to infer age). We are worried that when using a 2 sigma (or higher) distance criterion, huge inferred LPM parameter may suggest to the reader that the tracers are of no use. We added the 10% criterion to add another level of check assessing relative distance in addition to absolute distance of the cloud as per 1 sigma criterion.

–> In general, a variety of objective functions (which our criterion in principle is), is increasingly used in the hydrological modelling community suggesting that there is no one criterion that should be applied everywhere. –> We intend to include a note on the relative novelty of this approach and highlight that its general applicability needs to be assessed further for other datasets.

Technical Corrections Attempting to determine a MRT of 150 years with the given tracers (P. 3 line 22) is too ambitious and does not acknowledge the high quality of LPM presentation of the rest of the paper. None of the discussed tracers is sensitive to water recharged prior to 1950 (not even with the high sensitivity reached by Uwe for tritium). This is 67 years, not 150. Even using MRT instead of “age”: an EPM with an E/PM

of 0.1 (bottom row in plots of figure 15-20) and MRT of 75 years contains none of the tracers (all water in it is >67.5years old), and only <> 10%”. This is a strange use of the symbols “<>”. I think a better way to express what you mean is “disagreement

–> Thanks for the above comment. To clarify, a water with MRT 75y and E/PM 0.1 contains 59% of water younger than 67.5 years. Water with MRT 150 years still contains 33% of water younger than 67.5 years and therefore contains significant amounts of tritium. For this model example we can detect up to 250 years MRT. So by saying 150 years we are not over-ambitious. However, we agree that for such old (nearly tritium-free) waters, the aggregation error is large – the old component of the water could be thousands of years old and therefore the true mean age be significantly older [see e.g. Stewart et al., 2016 - doi:10.5194/hess-2016-532]. We intend to include a sentence or two (perhaps a footnote) to explain the above more clearly.

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