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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Influence of input and parameter uncertainty on the prediction of catchment-scale groundwater travel time distributions" *by* Miao Jing et al.

Anonymous Referee #1

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General Comments In the paper "Influence of input and parameter uncertainty on the prediction of catchment-scale groundwater travel time distributions" authors Jing et al. use particle tracking on a spatially-distributed steady-state groundwater model to compute Travel Time Distributions, Mean Travel Times and StorAge Selection functions. They vary the hydraulic conductivity and recharge in the model and explore the variation in the resulting TTDs. The calculated TTDs are compared with an exponential form of the TTD.

Significance The research is significant, and fits in the scope of several recent papers on TTDs, SAS functions and using distributed models to calculate these. More knowl-

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edge on the effect of input and parameter uncertainty on TTDs is very welcome. It is interesting to see a study in which TTDs are calculated using several parameter variations in a distributed groundwater model.

General comments: However, the grammar and language of the paper is not up to publication standard. Because errors were many, I have not focussed on this in the current review. For example, Line 1 (page 2) needs 'the' before 'Travel/transit time' and needs 'a description' instead of 'an description'. This continues throughout the manuscript and needs significant work. The manuscript can be shortened and more to the point as it contains quite some repetition.

Overall, the paper lacks sufficient in-depth discussion and conclusions. Several observations are made, but no process-based explanations are given. In addition, several important recently published papers were overlooked.

A considerable amount of work is required both on language and content, but the current manuscript offers a good basis for this.

Specific Comments: P1L1 refers to Page 1 Line 1.

P2L7: Suggested reference Wang et al., 2016 STOTEN

P3L15: 'threaten', what is meant by this?

P3L16-17: 'The combination of expert knowledge and parameterization is generally recommended in hydrogeological modelling.' This sentence can be removed as it does not add much.

P3L24-35: This is a list of earlier research. But what does it add? What are the conclusions/implications for the current study?

P4: An important assumption in the paper is steady-state groundwater flow. However it is unclear if the mHM model is steady state as well. What exactly is modelled by which model? What is meant by 'terrestrial hydrological processes'? Was the mHM model

only used to compute realistic values for recharge in the OGS model?

P5L3: is it really needed to give these well-known Equations?

P5L7 & Equation 2: What about horizontal groundwater flow? Was only vertical flow modelled?

P5L10-11: 'The functionality. . . by Part et al. (2008)' is not needed.

Section 2.2: is it needed to explain the RWPT in such detail? Especially since it is explained in the referred papers. This distracts from the current study.

P6L1: Suggest adding 'analytical' to the paragraph header.

P6L6-7: Repetition of P4L32-33.

P6L8: 'output flux (Q1, Q2, etc)': in a steady state system Q would not vary.

P6L9: Define 'T' and 't'.

Eq10: First introduce SAS functions. Also refer to Figure 9a here.

P6L21: Define 'RTD', not mentioned earlier.

P6L26: Maybe add some references to TTD literature where Exponential TTDs are used.

P6-7: Unclear how Equations 13 and 14 follow from Eq9, 10, 13. These equations possibly need check (or references).

Generally section 2.3 is quite hard to follow. Which equations are needed for the current study?

P7L11: 'As indicated in Bayes equation': which equation is this?

P7L23: Suggest shifting order of paragraphs. Start with Site Description. Then Numerical Model & Model setup. Then analytical model?

P7L27: ‘164 m’: above Mean Sea Level?

P8L5: ‘5 in km, 4 in ku,. . .’: these terms have not been introduced here yet. Move to later, after P8L16.

P8L19: This recharge is the recharge calculated by the mHM model right? This remains unclear here. Same for P8L26, these are from the mHM model?

P8L29-30: spatially distributed conductivity fields?

P9Figure1: Show the location in Germany of the study area. Indicate which layers are aquifers and which aquitards. In the legend, give the full names. At this moment the hydrogeology is not clear from this Figure.

P9L5: ‘the model’: which model?

P10Table1: Possibly use Hydraulic conductivity in m/d. Also, it would help to use more significant numbers, at this moment it’s hard to compare the values as the differences are hidden in the small superscripts.

P10L2-3: Repetition of P8L29-30.

P10L5-6: All parameters sets gave a good fit? What was the definition of ‘compatible’?

P10L7 injected on top of the land surface or groundwater table (top of groundwater model).

P10L11: Repetition of P10L7-8.

P11L1-2: Present how much recharge (mm) each particle represent.

P11L12-13: Isn’t the porosity 0.2 in all model runs? Or was this varied as well?

P11L15: This is repetition

P12Table2: What is the Composite parameter sensitivity? What does this table show? More this table to the Discussion where it is referred to.

P12L18-20: unclear what was exactly done.

P13L3-P14L2: Move to Methods.

P14L4: Sensitive to the hydraulic conductivity of the Middle muschelkalk?

P14L11-12: You can add that this is 'because the conductivity increases with increasing recharge and keeping the same groundwater head'.

P14L15: Whether a RMSE of <4.6m is sufficient depends on the mean/variation present. For instance, in a flat area this would not be sufficient. What is the mean groundwater level?

P15Figure6: This Figure is unclear and does not add much to the paper. Consider removing.

P15L2: What is R5K1?

P15L3: Do the deep low-permeable geological layers act as aquifers in other scenarios? Same for P16L9.

P15L5: '400 hydraulic conductivity fields': Shouldn't this be 50?

P15L6: Refer to Equation (12?)

P15L11: Why is this not surprising based on Eq. 16?

P15L15-16: How is the analytical exponential TTD fitted? Which parameters?

P16L23: Figure 9c does not exist.

P16L24-25: The difference between the SAS-functions under different recharge realizations is moderate. But there still is a difference, how do you explain this difference? Generally it is assumed that SAS functions only react to internal changes (changing groundwater flow paths).

P17Figure7: Add to the legends what the black line represents. Give the panels clear

titles: ‘R1, R2’. Currently isn’t unclear that the panels are the results from the different recharge scenarios.

P17L2-3: Repetition of P16.

P17L3-4: The system does not change to a preference of old water. But there is still significant variation (more or less preference for younger water). How do you explain this? Is it not logical to see changes when the hydraulic conductivity of different layers is changed? I would hypothesize that groundwater flow becomes more shallow or deeper as a result, leading to changes in the TTD and SAS functions.

P18Figure8b: Why use 1/J? Not J? A lower MTT with higher recharge is obvious, as more water is passing through the system in the same time (same conductivity). Showing the inverse makes this confusing.

P19Figure10: The inset in Figure 10a is unclear. Just give the numbers for the MTTs.

P19: Section 4.4 is very interesting and deserved more space in the paper. What is the effect of spatial changes in flow paths on TTDs and SAS functions?

P20L4-7: Combine these sentences.

P20L10 & L14: Repetition.

P20L14-17: Unclear. Need revision.

P20L27 & L30: Repetition.

P20L30: ‘sensitive to the spatial pattern of recharge’. This is interesting and deserves more discussion. At the moment it’s only presented as a result. But why is the TTD different? What determines this? When does the TTD shift to more younger discharge and when to older? With spatial differences in recharge the assumptions in Eq. 16 are not met.

P20L35 – P21L1: Repetition.

P21L6: ‘the analytical solution using Eq. 12 may underestimate the MTT’: Always underestimate? Or can it also overestimate the MTT?

P21L12: ‘aggregation error’ is mentioned in P2L31, and here. Without reading the refered papers, it is unclear what is meant by this. Either remove this, or give more explanation.

P21L18: But Figure 9b showed some differences, so it is sensitive? Also, is this conclusion is only valid for homogeneous recharge and conductivity?

P22L27-29: This sentence is unclear. Needs rewriting.

P23L1: Conclusion 2 is not a conclusion. An idealized aquifer system is one of the assumptions for the analytical solution.

P23L7: What exactly are the new possibilities? Numerical simulations were already combined with SAS functions, see e.g. these recent papers (also consider referring to these papers and using them in the introduction/discussion): Remondi, F., Kirchner, J.W., Burlando, P., Fatichi, S., 2018. Water Flux Tracking With a Distributed Hydrological Model to Quantify Controls on the Spatiotemporal Variability of Transit Time Distributions. Water Resour. Res. 3081–3099. doi:10.1002/2017WR021689 Kaandorp, V.P., de Louw, P.G.B., van der Velde, Y., Broers, H.P., 2018. Transient Groundwater Travel Time Distributions and Age-Ranked Storage-Discharge Relationships of Three Lowland Catchments. Water Resour. Res. 1–18. doi:10.1029/2017WR022461 Yang, J., Heidbüchel, I., Musolff, A., Reinstorf, F., Fleckenstein, J.H., 2018. Exploring the Dynamics of Transit Times and Subsurface Mixing in a Small Agricultural Catchment. Water Resour. Res. 2317–2335. doi:10.1002/2017WR021896

P23L9-11: As mentioned before, this is one of the interesting observations. Consider adding more detail to this part of the study.

Technical Corrections

As stated before, the paper needs significant rewriting. It contains many typing errors

(e.g. P2L22 ‘„’, P2L24 ‘StorAge Secletion’, P2L26 ‘the the’) which could have been found using a spelling checker, spelling errors (e.g. P2L29 ‘thorough’) and generally language is not up to publication standard.

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