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Geoscientific Model Development Discussions

Interactive comment on "*tran*-SAS v1.0: a numerical model to compute catchment-scale hydrologic *tran*sport using StorAge Selection functions" *by* Paolo Benettin and Enrico Bertuzzo

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We thank Referee 3 for his/her positive evaluation of the model

> *The authors present a very useful Matlab implementation of the StorAge Selection modeling framework.*
> *The implementation is essentially a solute transport model, because the solute concentrations are one of the state variables. With the SAS framework it is possible to calculate solute concentrations "offline", by storing the travel time distribution of stream flow for select (sampled) times, and multiplying these with the tracer input history. This is efficient for a small number of samples and a large*

> *number of tracers. Perhaps not a common case.*
> *From the manuscript, it is not clear if the model supports simultaneous calculation of multiple solutes. Perhaps I missed that. It would be useful.*

The present implementation of the SAS framework is chiefly oriented to modeling the time-evolution of one solute in a hydrologic system. Extending the code to the case of multiple solutes is an easy task because the water carrier (and its transit time distributions) remains the same. Hence, one only needs to duplicate the equations that involve solute transport (or re-run the code with modified initial and boundary conditions). We prefer to keep this basic code simple and intuitive, and let the user adapt the code to more advanced transport problems.

> *I would like to see a stronger encouragement by the authors to test the parameter space for each new case. The example parameters are very hypothetical.*

We agree with Referee 3 that the parameter space should be widely explored and we will highlight this point in the revised version.

> *The model description is accurate and easy to understand (for someone who has worked with a different implementation of a SAS model). I hope one of the other reviewers is a "SAS dummy" who can ask the questions that seem obvious to me.*

We thank Referee 3 as, indeed, we put quite some effort to make the code description and implementation easy to understand.

> *I have a few comments specific to the text: P5 L19, Eq 6: This implementation is equivalent to the fractional StorAge Selection (fSAS) implementation, right?*

Mathematically, equation (6) becomes a fSAS after the variable transformation $S_T(T,t) \rightarrow f(T,t) = S_T(T,t)/S(t)$.

> *Section 3.3: I would like the authors to elaborate on the discussion of the "old pool". Transient tracers like tritium and chlorine-36 demand that the age distribu-*

tion of the old pool is accurately represented. Or at least in the concentration in the "old pool" needs to be represented.

We agree with Referee 3. The problem of what is to be considered as “old” also depends on the considered tracer and its characteristic input timescales. In the case of tracers like tritium and chlorine-36, a much longer spin-up is advised to limit the impact of apriori assumptions on the initial old pool concentration. Also in this case a much longer timestep (e.g. weeks) could be used in the computations.

P9 L6: "long term" = 4 years? P9 L13: S0=1000? mm? P9 L11: I understand the parameterization of the example is not intended to represent the hydrogeological conditions of the particular data set. Nevertheless, I find the random sample (kET=1) surprising, as I would expect the vegetation to have even the slightest preference for younger water. Perhaps the authors can warn the reader that these parameters should not be considered "valid" for any catchment and encourage the user of the tranSAS to vary all parameters of the example case drastically if applied to a specific setting to test the sensitivity.

As mentioned in previous comments, we fully agree with Referee 3 on this point. These were just hypothetical parameters (although they are similar to parameters found in small catchments in wet climates, e.g. Benettin et al., 2017) and should not be taken as representative of a general catchment behavior. We will clarify this in the revised manuscript. We also believe that, thanks to the short computational times, the tranSAS code facilitates sensitivity analyses.

Figure 3d, please clarify that this is the stream flow TTD.
P10 L1: "solutes with a yearly period".... like stable isotopes of water? (These aren't really solutes.)

We will correct this, thanks for pointing it out.

P10 L8: The range in median ages can vary much more. It all depends on

the fictional parameters you enter into your model. It might be more relevant to compare the nonrandom-sampling cases with the random-sampling case. Or reiterate that any power with a k < 1 prefers younger water and will therefore have a younger TTDs (right? or is this not alwyas the case?)

Age estimates are typically more sensitive to model parameters than solute concentration estimates. We will specify this by expanding the discussion on the sensitivity of model results. The relationship between the age distribution and the value of parameter k is not straightforward as it also depends on which portion of the age distribution is considered. We will modify this paragraph to highlight the differences with respect to the random-sampling case.

P10 L10: This dilution example is interesting. Is it true that the stream solute concentration is the inverse of the TTD in the random sampling case (k=1)? It might be worth mentioning. The inverse problem, a step increase of a contaminant input relates more directly to the TTD. I do like this example because it is more optimistic about the potential to reduce environmental contamination. And it illustrates an important aspect of transient contaminant flow, that even with zero input, stream concentrations can increase due to the variable hydrology.

We thank Referee 3 for this positive comment.

P15 L6: "less than a second" for a 4 year time series? How much longer does the ode113 solution take?

On an ordinary PC, the test-case implementation (4 years spin-up + 4 years run, power-law SAS functions with k=0.7, 24-hour timestep) runs in less than a second for the modified Euler Scheme and in about 30 seconds for the ode113 solution.

P15 L28: "chronology of the inputs is irrelevant" Not quite sure how to interpret this. The chronology of a constant input decaying tracer (e.g. tritium for the last 30 years) is irrelevant, in the sense that it doesn't matter "when" the precipitation *entered the catchment, but it does matter "how long ago". I know what is menat, but it reads like this model is only relevant for tracers with input fluctuations, which isn't the case (as long as the tracer decays on relevant time scales).*

In our view, the impact of input "chronology" is twofold: it expresses the time-variability of the input and it also determines the residence time of the input in the system (traditionally seen as the interval between present time and entrance time). In this paragraph we wanted to warn the reader that sometimes solute concentration can be driven by factors that do not depend on when the input entered the system nor on how long it remained in the system. We will clarify this point.

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