

We would like to again thank the editor and reviewers for their thoughtful comments, which have greatly improved this manuscript. In our latest revision, we have addressed the additional comments from Dr. Troy Baisden. His suggestions are pasted below (in black) with our responses shown in red.

Reviewer (Troy Baisden) Comments on Revision 1

Overall, the response to review and revised manuscript is in good shape and I'm very pleased with the revised manuscript. I appreciated the constructive and generally well written responses to the review. I reiterate my view that this publication is the culmination of an extremely valuable piece of work, albeit one that probably became bigger than the authors imagined. It's completion is a considerable achievement, and although there are no guarantees, it has real potential to enable considerable progress in the field. I spotted some remaining quibbles (typos, lack of clarity in references, etc) which I outline at the end of this review, and somewhat of a lack of clarity in the additional key question introduced (where a typo or omitted word makes it hard to interpret meaning). And last, there is a substantive difference on the semantics of age, and transit vs residence times and alternate words for the same concepts. I've outlined some clear thoughts on this issue below, but the net effect is that the manuscript should be publishable without the need for further discussion if authors ensure the final version simply encourages users to be aware of the need to consider the concepts of age, transit, and residence or turnover times and the related definitions and assumptions in using IsRad.

Semantics of Age, Transit Time and Residence Time

In response to my comments noted against Line 45, I think there is necessarily a bit of an impasse regarding the use of "transit" time. It has minor implications here, and is an editorial issue in terms of communicating to a wide audience (e.g. across disciplines). Let's just say there remains a "muddle" that has been very usefully identified but not resolved (in my view) by work involving the authors, particularly Sierra et al 2017 (which is published as an "Opinion" article and not as a review, and in the journal *Global Change Biology* which is not likely to get good review representing the less 'biotic' of the earth system sciences).

The best solution for the publication of this work, explained in detail below, seems to be to use accessible language and/or suggest that more effort is needed to clarify workable definitions across disciplines. Given the purpose of this paper, I see no need to reach a forced resolution, but will try to clarify my view for the editor and authors given the response to the review comments.

The heart of my concern is that the technical language we use for specialised research should remain consistent with standard dictionaries and textbooks in the relevant (connected) disciplines. And, we should pay attention to it to the degree that misinterpretation or misunderstanding can cause severe errors. Starting with the dictionary, transit is strictly an adjective here, but normally defined as a noun: 1) carrying of people or things to one place or another; 2) the action of passing through a place. A verb definition is usually linked to (2). Similarly, "residence" has the relevant definition (noun): the fact of living in a particular place, and related concept of 'in residence'. In the response to reviews, the authors start with Bolin & Rodhe 1973, who carefully place residence time in parentheses after each introduction of transit time. Transit time is clearly meaningful and specific directly in relation to its dictionary definition (passing from one place to another) across areas of the earth system sciences including hydrology/hydrogeology, geomorphology and oceanography.

I think success within papers like Bolin and Rodhe as well as the others the authors point to in their response is that it can be insightful to conflate the concepts of residence times and transit times, where the boundaries of the system can be placed so that transport processes can be simplified or removed from consideration. I still think this is best considered a special case, but is definition dependent. The problem with generalising this equivalence may be that any such simplification relies on assumptions and understanding, which if ignored (and untrue) causes errors. These errors are most likely to occur and be compounded when there is a mismatch between specialised terminology and plain english, and it is an important (and sorrowfully annoying) role of reviewers and editors to try to prevent this, without carrying out a full modelling analysis or a review across several disciplines.

Author's Response to Reviews

essd-2019-55

In their response, the authors suggest that 'residence time' has been conflated with both age and transit time, but I think that is simply the result of it being the most commonly used term. It is in fact well introduced to many students in text books (see below). In addition, it may be useful to point to Maloszewski and Zuber (1982 J Hydrol 57:207) as an well-cited example where the conflation of all three (age, residence time and transit time) is clearly stated, and can be linked to the causation of significant problems over the years in applications. The problems with this particular work are relevant here because they have occurred in the interpretation of post-bomb tritium results, including time series, which has similar mathematical dynamics to soil radiocarbon. In my view, residence time can be usefully considered the same as transit time, but may also be useful to distinguish at different scales or in models where transport between reservoirs can be removed or collapsed (see Baisden et al 2013).

In this work, it would be ideal to maintain consistency with language used in standard/classic textbooks (which regularly define "residence time") in fields such as environmental modelling (Harte), ecosystem ecology (Odum), limnology (Vincent), isotope geology (Faure), biogeochemistry (Schlesinger) and geochemistry/geochemical modelling (Albarede). I have checked my collection of books in these fields (authors noted in the previous sentence), and none of these index transit time as key concept. If a more unusual term, such as transit time is used, and claimed to provide insights or improved definitions, it still needs to be defined – which is not done in the revised manuscript. Oblique citations are not enough. Given prevalence in textbooks in relevant disciplines, the unexplained but strongly worded decision by the authors to avoid the use of the widely used 'residence time' concept is problematic, and seemingly circular if they return to Bolin and Rodhe 1973 to explain this. Ultimately, there probably isn't reason in this paper to discuss or deal with where the terminology fails or causes confusion around areas such as non-steady state systems, and just a need to define rationale and future use of the ISRAD. Many of the authors target better understanding of transport as a component of the C cycle as a key goal, both down through profiles and across landscapes/catchments. The latter is increasingly recognised as important in the carbon cycle on the timescale at which radiocarbon can be used to constrain dynamics. As a result, it would be good to be careful to avoid "muddle" and potential bias, and retain options for further innovation and clarification in terminology associated with these terms.

So for this paper, I don't see much to do except be mindful that the authors and I agree that there is an important problem of semantics to be aware of, but because I am not convinced of their solution, the problem can be framed minimally within the paper so that use of the database can help the field move toward consistent solutions to these semantic issues – ultimately clearly quantifying and communicating the dynamics of systems. I provide some suggestions for slight changes or notes to accept the text as is below.

Author Response

We appreciate the effort of Dr. Baisden in helping to clarify the terminology issues that arise when trying to disentangle different aspects of the timescales at which carbon is stored and cycled in soils.

We agree in that the term 'residence time' has been widely used in the past to infer something about the dynamics and timescales of carbon cycling. However, when the problem is analyzed in more detail, it is clear that one needs to differentiate between the age of carbon stored in the system versus the age of carbon in the output flux. We chose calling the later 'transit time' because there is a history of attempts to disentangle these concepts, trying to avoid the more ambiguous term 'residence time' that could be interpreted as both.

Following Dr. Baisden suggestion, we provide new definitions of these terms in the manuscript and equate transit time to residence time. We provide the following definitions:

Carbon age: is the age of carbon stored in the soil, since the time it enters until a time of observation.

Transit (residence) time: is the time that carbon needs to pass through the soil system, since the time it enters until it is observed in the output flux. This output flux can be defined as the respired CO₂ flux leaving the soil or the amount of DOC in the runoff flux.

Author's Response to Reviews

essd-2019-55

We hope these definitions not only help to better clarify the concepts introduced in the manuscript, but also help to better understand the different types of data provided in the database.

Specific points

L2 remove 'the' at end of line? There is odd syntax resulting from preceding terrestrial ecosystem dynamics and not parallel to use of dynamics earlier in sentence, implying dynamics of two related systems.

We have made the suggested change.

L22 Use of terms describing dynamics seems fine here, but compare to L 106.

We left the terminology as stands here but made the suggested changes at L106.

L52 There is no 2001 publication by Baisden or Baisden et al. 2001. I apologise - this may relate back to a typo in my review. Presumably Baisden et al 2002a is intended, although this would now feel slightly odd when placed here because it contains a comparison of methodologies including both bulk and fractionation. (Most of the fractionation is in Baisden et al 2002b, but specialised fractionation below the A horizon is only in 2002a.) Overall, I suggest perhaps reconsidering how this sentence is split and referenced, but think the message here is about right. It might be simple to move reference to the end? The only caveat is that the inclusion of 'synthetic constraint' (resulting from the inclusion of NPP or related measures to constrain total C turnover from all pools) could be useful as defined/promoted by Baisden and Keller 2013, but also applied in Baisden et al 2002a (and reexamined in Baisden and Parfitt 2007)

We thank Dr. Baisden for pointing out this discrepancy, we have modified our citations of his work based on this suggestions.

L58 and elsewhere Baisden is spelled wrong in "Basiden" and Keller...

We apologize for this spelling error, which occurred in our reference tracking software and, as a result, was propagated throughout the manuscript. We have corrected all instances of this mistake.

L63 Is "transit" really intended here? Can residence time(s) be added in parenthesis as in Bolin and Rodhe as noted in the discussion above. Or 'turnover times' because this is clearer when applied to separate fractions?

As per Dr. Baisden's suggestions we have added additional clarification for our definitions and also added "residence" in parenthesis.

L 77 There's a noticeable typo where I can't figure out what was intended in the middle of the now three questions "2) what factors determine the fraction of organic inputs to soil that are lost, retained, or transferred each reservoir;" I might suggest rephrasing this to better pick up on all four main processes (additions, removals, transfers, transformations) recognised traditional in pedology and extended to ecosystem science across the suite of three questions. If so, question 1 describes inputs and the partitioning of inputs, "what factors determine rates at which SOM in each reservoir is lost, or retained, or transferred or transformed within the soil?" This approach leaves the third question as a part of transformations (to more protected forms).

We have modified these questions for clarity and to address the four main pedological processes reference by Dr. Baisden. The questions now read as:

"...(1) what are the controls on the partitioning of organic inputs between soil reservoirs cycling over different timescales; (2) what factors determine rates at which SOM in each reservoir is lost, retained, or transferred within the soil; and (3) which mechanisms contribute to transformation of SOM to stabilized or more protected forms?"

L96 Now that Golchin et al 1994 is cited, I'd suggest referencing it here with regard to sonication and occluded fractions?

We have added this reference to the sentence describing sonication and occluded fractions, as suggested.

L106 I don't strongly disagree with what is said here, but the insight provided by the response to review suggests that the following text "as well as differentiating between the mean age and the transit time for the whole soil"

Author's Response to Reviews

essd-2019-55

might be usefully changed to “as well as differentiating between different measures of dynamics ranging from mean age to the transit time for the whole soil”

We have incorporated this suggested change.

As a last point, I don't have a specific location to recommend, but I do note that giving the authors an opportunity to consider inserting or further emphasising a sentence or two somewhere outline the reasons why the definitions and assumptions that cause difficulty in the interpretation of the concepts of age, transit time, residence time etc deserve focus for users of IsRad.

We agree with Dr. Baisden that this is an important point to emphasize. We have added the following sentence: *“As the assumptions required for modeling radiocarbon data can lead to confusion in the terminology and concepts of SOM dynamics, it is imperative that we archive radiocarbon measurements in order to preserve the ability to reevaluate calculations and compare data across different modeling frameworks.”* To the end of the 3rd paragraph to highlight how the database is an important tool for addressing confusion or disagreement in concepts of SOM dynamics.