1 Response to reviewer 1 (Victor Brovkin)

We would like to thank Victor Brovkin for providing a review on our manuscript. The main comments of his review are provided below in italics, with our reply in normal font.

- *There are, of course, limitations of methods used in the study: for example, provided numerical package is based on linear and equilibrium assumptions. These assumptions, of course, do not cover all possible types of equations for soil carbon turnover, but provide a good start for the 14C modelling.*

  We indeed acknowledge that our approach has limitations such as the use of linear models, but we would like to clarify that this approach does not rely on the equilibrium assumption as mentioned by the reviewer. This is stated in the form of the general radiocarbon model of equation (2):

  $$\frac{d^{14}\vec{C}(t)}{dt} = \vec{I}_{^{14}C}(t) + \mathbf{A}(t)^{14}\vec{C}(t) - \lambda^{14}\vec{C}(t)$$

  where the inputs of radiocarbon to the soil $\vec{I}_{^{14}C}(t)$ and the decomposition operator $\mathbf{A}(t)$ are time-dependent. We can therefore solve the model for any transient behavior of the inputs or the decomposition rates, which implies that we do not need to rely on the equilibrium assumption to solve our models. The assumption of equilibrium is only needed to calculate the mean transit time. This is explained in section 2.3.1.

- *I found notations in the equations in the section 2.3 confusing. In particular, I am confused with usage of term T (it is used in section 2.3.1, but formally defined in section 2.3.2). T stays for the transit time (p.3168, l. 14; p. 3169, l. 6), but also just for time (p. 3169, l. 7). I would suggest always using small letter t for time. Since the transit time T could be time-dependent, it would make sense to note it as T(t), e.g. T(t_0), and not use time as a lower index as in p. 3168, l. 14.*

  We acknowledge that the treatment of t and T in the text may be confusing, but it is actually correct the way it was originally written. The key point is that for linear time invariant systems the time solution for the output $O(t)$ is equal to the transit time distribution $\psi(T)$, as shown by Nir and Lewis (1975) and Manzoni et al. (2009). The implication of this remarkable result is that $t = T$. We made changes to the text to make this result more obvious and explicit, and avoid any confusion.

- *Eq. 13: please either provide an equation for calculating the transit time density* `psi_t_0` *or explain it in words, because it is defined only in the next section.*

  The issue here is that the exact definition of the density function depends on the assumptions made about the system. For the assumption of a LTI system, the definition of this density function is provided in the subsequent paragraph. We expect to provide a more general definition in a forthcoming publication in which we can calculate the density function for any time t. In the text we tried to make this more explicit.

- *Eq.13: This form of integral notation confuses me. The right part is a function of t (time), but t is absent in the left part of the equation. Also, why the integral boundaries are from 0 to t-t_start? Should not they be from t_start to t_0? What is changing from 0 to t t0: T or t? Should not it be psi_t and not psi_t_0?*

  There was indeed an error in equation (13). The upper limit of integration is not a variable but a constant, from the time the simulation start t_{start} until the time of observation t_{obs}. Originally we intended to used t_0 for this upper limit, but this was mistaken. We also realized that this notation may be confusing, so we changed t_0 to t_{obs} for clarity.

- *p.3169, l. 7: "**I**/I" is confusing, because symbols "**I**" and "I" look very similar. Could you use another symbol for the sum?*

  We changed to sum to the symbol $\Sigma\vec{I}$, which should be now more clear.

- *p.3169, l. 9: "Translated to the language of an ODE solver, an impulsive input becomes a vector of initial conditions I/l at time T = 0, and Sr the release flux of the solution of the initial value problem observed at time T" I cannot understand this sentence. See my comment on using T as time above.*

  We reworded this paragraph to make the point more clear. The main idea is that the time dependent solution of the system for the outputs after an inpulsive input (release or respiration flux) should be equivalent to the transit time density function. We hope the new version presents this idea clearly.

- *P. 3172, l. 17: Where is Table S3? I miss it in supplementary.*

  In the text we say Table S3 therein, referring to the paper Hua et al. (2013). In other words, this table is in the supplementary material of Hua et al. (2013). We made this more explicit in the new version of the manuscript.

- *p. 3172, l 14 replace form with from*

  Done

- *Fig. 5 needs better explanation in the figure caption and more discussion in the text. E.g., what are units on axis? What do numbers in the matrix mean and what is a meaning of dots in the scatter diagrams?*

  We added more detail to the figure caption and expanded the description in section 3.3 as suggested.

2 Response to reviewer 2

We would like to than the anonymous reviewer for her/his helpful comments. The main comments from the review are provided below in italics, with our reply in normal font.
General comments:

- *My major concern is the lack of illustration/discussion of relation among the three major topics: "General radiocarbon model" (Section 2.1), "Mean transit time" (Section 2.3), and "Atmospheric radiocarbon datasets" (Section 2.4.2).*

  We agree with the reviewer in that we do not discuss the relations between these different sections and how these different components of our modeling framework can be used in combination to answer more specific scientific questions. We added a Discussion section that addresses these relations.

- *I did not see the necessity to include radiocarbon modeling for the estimation of mean transit time*

  The estimations of mean transit times are indeed independent from the modeling of radiocarbon. However, the topics are related and there is a general perception that radiocarbon measurements help to estimate the residence time of carbon in soils or ecosystems. We think this is an important aspect to address and added this topic to the new Discussion section.

- *In addition, the feedback from atmospheric radiocarbon to soil radiocarbon through plant absorption of CO2 was not fully elucidated*

  Yes, we forgot to add a discussion about the time-lag of radiocarbon in vegetation before it is incorporated in the soil. The argument `inputFc` of the function `GeneralModel_14` includes the option to specify the time-lag radiocarbon spends in the vegetation before it enters the soil system. In addition, one can use a simple pool structure to more specifically introduce this time-lag of radiocarbon in vegetation. We discuss these ideas with more detail in the new version of the manuscript.

Technical comments:

- *Page 3169, the following statement confused me, "the transit time density distribution $\psi(T)\ldots$ is identical to the output O (T) observed at time T ...?. $\psi(T)$ is a PDF (probability density function), while O(T) is "the cumulative output" (see your definition on page 3168) , I could not understand why they could be identical to each other?*

  We understand this argument may be confusing, but it is actually an important result in reservoir theory. The derivation of this result is presented in Nir and Lewis (1975), and it wouldn't be within the scope of this manuscript to rewrite the long-derivation presented there. We tried however to explain this better in the new version.

- *Eq. 15, please further explain Sr(I/I, 0, T)? Does it mean that "Sr" is a function of I/I with the period from t = 0 to t = T? How to construct this function? Please give an example if possible.*

  The term S_r is a function that represents the numerical solution of the output flux that takes as initial conditions an impulsive input. We reworded this paragraph for clarity.

- *Page 3175, the authors reported the results for the mean residence time (MRT). However, it's unclear how to practically compute the MRT since the PDF for residence time (T) was not clearly defined in section 2.3.*

  This was a mistake in the text. Instead of mean residence time we meant mean transit time, which is explicitly defined in section 2.3. We made this correction in the text.

- *Page 3170, please explain the meaning of the non-zero eigenvalues of the matrix A.*

  The non-zero eigenvalues was part of the original definition of τ_{cycle} given by Lasaga (1980). From the work of Bolker et al. (1998), it is clear that linear decomposition models do not show zero eigenvalues, only decay functions with eigenvalues with real negative part. For this reason we removed the reference to non-zero eigenvalues from the text and just define λ_i as the eigenvalues of the matrix $\mathbf{A}$.

- *Page 3171: lambda, the "-" sign for the parameter value is not necessary since the "-" sign has been indicated in Eq. 4.*

  Good point. The negative sign was removed.

- *Page 3172: what's the difference between datasets "IntCal09" and "IntCal13"? temporal resolution? It seems that the latter one has a finer temporal resolution than the former one. Can we generate "IntCal09" from "IntCal13"? Is it necessary to keep both?*

  IntCal13 is simply an updated and revised version of IntCal09 that includes additional data, finer temporal resolution, and improved the calculation of uncertainties. They both are internationally-ratified curves by the geochronology community. The reason we included both curves in SoilR is that we can replicate previous analysis performed before the availability of the new curve. This information was introduced in the new version of the manuscript.

- *Page 3172: what are the "uncertainty values" for datasets "IntCal09" and "IntCal13"?*

  The calibration curves are created using a Bayesian procedure that takes the observed radiocarbon values at each point in time and adjust a state-space model producing a posterior distribution for each time point. These uncertainties reported are the standard deviation of the posterior distribution at each time point. This is described with detail in Niu et al (2013) and Reimer et al. (2013)

- *Fig.5: based on the values for k1, k2, and k3, i.e., negative values, I presume these are log-transformed values, which was not indicated in the fig caption.*

  The parameter values for k_1, k_2, and k_3 were not log-transformed. They were erroneously plotted as negative values, but we corrected this in the new version.

- *Fig. 6: what are the "prediction intervals"? standard deviations or 95% (90%?) confidence intervals?*

  They are 80 and 95% confidence intervals. This information was added to the figure caption.

Technical corrections:

- *Page 3166: 13C − > 14C*

  This is indeed 13C fractionation. This is a correction typically given by radiocarbon labs to account for possible mass fraction effects on a sample. For details see ref. Mook and van der Plicht (1999).

- *Page 3179, Line 5, "in or calculations" − > "in our calculations"*

  Done.

- *Fig. 5, "p3− >k4"− >"p3− >k3"*

  Done.

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