Point-by-point responses to all review comments

NOTE: To facilitate the evaluation of our responses, original review comments are listed first in their originals (**in bold font**), followed by our itemized responses (in red). An annotated version of revised manuscripts is attached.

Referee #1:

We thank the reviewer for the constructive comments and suggestions, which are in black bold text below. Our itemized response is followed (in red).

1. **Equation (2): Please denote the unit of DOC leaching flux.**

Response: We added the unit of DOC leaching flux (g C m^{-2} s^{-1}). Please refer to Line 157.

2. **Line 176: "Riverine DOC is mainly derived from organic carbon leaching processes in soil"; some literature support is required here.**

Response: We added corresponding references as suggested (Gommet et al., 2022; Li et al., 2019). Please refer to Line 136.

3. **Line 189-190: where is the reference for choosing this weighting coefficient?**

Response: We chose this coefficient according to the previous studies (Liu et al., 2019; Zou et al., 2014), and we added corresponding references at the same time. Please refer to Lines 229-230.

4. **Section 3.1: I suggest adding a table to show the main datasets used for model running and validation in this study.**

Response: Thanks for your valuable suggestion. We added a table to summarize the main datasets used in this study. Please refer to Table 1.

5. **Line 221: Please introduce the details for the human water use activity dataset. A description of what data sources were used?**

Response: Based on the comment, we revised the manuscript. Please refer to Lines 260-265.

6. **Line 205: Only the fluxes into the soil carbon pool after surface water extraction are described. What about groundwater extraction?**

Response: Because groundwater extraction usually occurs in situ and will pass through the filtering effect of the soil layer, we hypothesized the part of DOC that returned to soil with groundwater extraction was ignored in our parameterization scheme.

7. **In Section 2.1, the parameters mentioned in the developed soil and river carbon dynamics parameterization scheme are uniform or spatially varying?**

Response: The parameters mentioned in our developed schemes are uniform. In fact, it does not correspond to spatial heterogeneity, and we will further refine and modify the parameterization scheme in our future work. The current parameterization scheme has reasonable accuracy in the simulation results, so we believe that our model can be applied to global-scale riverine DOC transport simulation studies.

8. **Line 252: Figures 3a and 3c seem to underestimate. Please check carefully and modify.**

Response: Thank you so much for your careful check. We modified it in our manuscript. Please refer to Line 294.

9. **Line 273: Are constants (0.3 and 0.7) in equations the same for the whole world?**

Response: Yes, we set the constant due to the limitation of data.

10. **This study developed a model to describe the soil carbon leaching and riverine carbon transport processes, which are not well described in previous land surface models. But the discussion of current uncertainties and limitations in modeling is missing. It should be discussed more.**

Response: Thank you for your advice. We added some discussion of current uncertainties and limitations in our manuscript. Please refer to Lines 459-463.

11. **Line 354-355: The authors state that the three rivers were affected by minor groundwater regulation. Please briefly explain the impact and the reasons.**

Response: In our selected rivers, only the Mississippi, Yangtze, and Ganges rivers were affected by minor groundwater regulation, which usually occurred during the dry period, where DOC export increased slightly in the Mississippi and Ganges rivers because of higher soil leaching due to irrigation, while DOC export decreased in the Yangtze River due to a significant reduction in river discharge. This also corresponds to the results in Section 4.3.

12. **In section 5, some words about future work are needed.**

Response: Thank you for your suggestion. We added some discussion about future work in our manuscript. Please refer to Lines 463-466.

Referee #2:

We thank the reviewer for the constructive comments and suggestions, which are in black bold text below. Our itemized response is followed (in red).

The presentation can be made clearer. The authors should make an effort to make it more accessible to non-modelers (like me), and to readers who want to take home the message without detailed reading of the methods. For example, the different simulations of control conditions and different parts of water regulation considered (CTL, EXPA, EXPB) are in several of the figures presented without explanation or spelling out.

Response: Thank you very much for your suggestion. We modified the subtitle and legend of Fig. 4~12 to make it easier for the reader to understand.

Is there some way to add (or more carefully discuss) uncertainty ranges around the various estimates and graphs? The current version presents and compares several numbers with 3-4 significant digits, with no confidence intervals.

Response: Based on your comment, we added a standard deviation after the estimated value to indicate its uncertainty range (mean ± std). Please see Lines 27, 300, 422, 430, and 453.

Table 2 could be expanded, it appears incomplete. There are several additional estimates of DOC export (possible resulting in a higher median than presented in the manuscript). Some (but not all) are cited in Drake et al. 2018 (Limnol Oceanogr Letters).

Response: Thanks for your detailed comment. We have read the article you mentioned and found that most of the carbon flux which export to the ocean is estimated to be 0.95 Pg C yr^{-1}, but it includes all forms of carbon in rivers. We set the organic carbon (OC) / inorganic carbon (IC) ratio to 0.4/0.5, in which 55% of OC flux is dissolved (DOC). Finally, we calculated that the riverine DOC export flux was 232.22 Tg C yr^{-1}. We added this result to Table 3 (in the revised manuscript) at the same time. Besides, we also added another result from van Hoek et al. (2021).

I do not understand how transformations in the regulated and unregulated waters are treated. The methods (line 196) say that "migration transformation" is ignored in the model, and loss rate is assumed equal in reservoirs and rivers. In contrast, one of the model results (line 287) is suggested to be due to increased residence time by the construction of reservoirs, causing increased DOC removal. How is this compatible?

Response: Thank you so much for your careful check. We revised this sentence to "This may be related to the fact that the reservoir adjusting the river discharge and intercepting the riverine DOC." Please refer to Lines 334-335.

Line 292: "alpine" should be "arctic"

Response: We revised it in our manuscript. Please refer to Line 341.

Referee #3:

We thank the reviewer for the constructive comments and suggestions, which are in black bold text below. Our itemized response is followed (in red).

Line 30: Rivers are a pipe linking the two major carbon pools of terrestrial and ocean ecosystems. Maybe "aquatic ecosystems"? Since the river also connects to the lake, etc.

Response: Thanks for your comment. Rivers indeed connect other inland aquatic systems such as lakes, but here we want to express that rivers link two major carbon pools: the land and the ocean.

Line 31: IPCC AR5, full name if it is the first-time usage

Response: We revised it. Please refer to Lines 31-32.

Line 34: "This", what this is referred to?

Response: This means that the annual DOC transported from terrestrial ecosystems to the ocean via rivers is equivalent to about 1% of the global NPP of terrestrial ecosystems.

Line 35-37: Higher than what?   Consider breaking this long sentence to shorter ones.

Response: Thanks for your comment. It means riverine DOC is a rather highly reactive organic carbon. And we revised it as you suggest. Please refer to Line 36.

Line 45: May define DOC leaching before use? Also, consider breaking this sentence into shorter ones.

Response: Thanks for your comment, we revised it. Please refer to Lines 44-47.

Line 61: There are at least some time series DOC measurements in some datasets, even if they are not long-term measurements.

Response: Thank you so much for your careful check. We revised it. Please refer to Line 73.

Line 90: Why not use the same resolution, such as 0.5 degrees, for land and river?

Response: Due to the limitation of available computing resources, the spatial resolution of the model was fixed to 0.9° × 1.25° for land, and 0.5° × 0.5° for river. Besides, since river module is typically run at a finer resolution than land, the land variables are interpolated to the river grid by coupler in the model.

Line 103: What do you mean by linear RTM? More details are needed.

Response: CLM5.0 includes two river routing methods: RTM and MOSART. RTM is a linear reservoir method, which uses a linear transport scheme to route water from each grid cell to its downstream neighboring grid cell. Please refer to Lines 111-116.

Line 124: What are upstream and downstream, can you link these processes in Figure 1 so readers can understand what Equation 1 is illustrating in Figure 1?

Response: Please refer to Lines 137-142. The transformation cascade is shown in Fig.R1. And transfers of carbon from upstream to downstream pools in the decomposition cascade are given as:

$$CF_{Lit1,SOM1} = CF_{Lit1}(1 - rf_{Lit1})$$

$$CF_{Lit2,SOM2} = CF_{Lit2}(1 - rf_{Lit2})$$

$$\ldots$$

$$CF_{SOM2,SOM3} = CF_{SOM2}(1 - rf_{SOM2})$$

For more details please see CHAPTER 21 of the CLM5.0 technical notes (Lawrence et al., 2018).

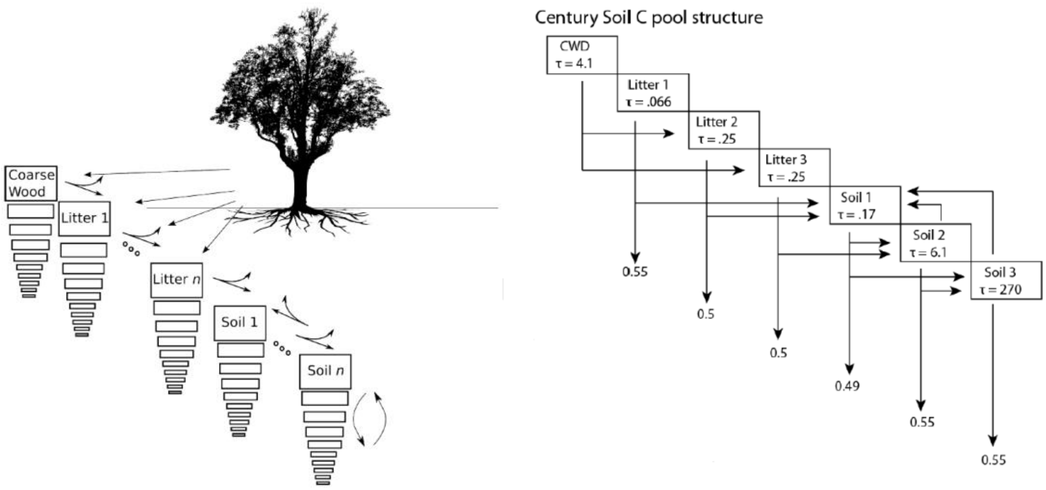

Figure R1: Schematic of decomposition model (Century model) in CLM. Pool structure, transitions, respired fractions (numbers at end of arrows, rf), and turnover times (numbers in boxes).

Line 132: The unit of DOC is inconsistent from Line 127. Normally, DOC concentration is expressed as mg C / L. Based on Equation 3, [DOC] is unitless.

Again in Line 139, you used another unit for [DOC] as mg g soil-1.

Please unify the DOC units.

Since you mentioned both adsorption and desorption, you should describe both processes and their equations.

Response: Thanks for your comment.

(1) The unit of [DOC] in our developed model is **g C kgH2O^{-1}**, which is calculated by dividing NS_{DOC} (g C m^{-2}) by WS_{tot_soil} (kgH_2O m^{-2}). In fact, **kgH2O** is equivalent to **L**, but in different expressions.
(2) In calculating the sorption coefficient of soil DOC, the concentration unit is normally **mg g soil^{-1}**, thus we made a unit conversion during the model calculations.
(3) We have described the adsorption and desorption processes. Please refer to Lines 163-171. In Eq. (5), RE is the amount of DOC desorbed (negative value) or adsorbed (positive value), calculated by the simple initial mass (IM) linear isotherm.

Line 153: I assume that Equation (7) DOC_leached is the LDOC? If so, you can make them the same. How about RDOC? How is it modeled?

Response: Thanks for your comment. In this study, the DOC runoff is defined as the soil DOC in surface runoff, and the DOC leaching is defined as the subsurface losses of DOC in soil water. Soil carbon loss (DOC_{loss}) is the flux (g C m^{-2} s^{-1}), while R_{DOC} and L_{DOC} are the flow (kg C s^{-1}), so they use different expressions. We revised it in our manuscript, please refer to Lines 150-162, 177-179.

Line 188: How are these coefficients obtained? Please provide some details or references.

Response: Thanks for your comment. We added the reference in our manuscript. Please refer to Lines 229-230.

Besides, how sw and gw are linked to DOC? For example, if there is SW extraction, then shouldn't it be included in Equation (8), such as a term to describe DOC extraction?

Response: Equation (8) is just the riverine DOC transport framework. Please see Sec. 2.5 for more information on how anthropogenic water regulation activities affect DOC transport.

Line 214: The land component is not 1 degree by 1 degree, so there is some inconsistency.

Response: In the land surface model, 0.9° × 1.25° is usually considered as 1 degree grid resolution.

Line 220: Is it ok to have spatial interplate dam/reservoir data? Maybe more details are needed to show how it was conducted.

Response: Thanks for your comment, we added a figure about spatial distribution of reservoir data and some details for reservoir operation scheme in the supplement.

Line 245: Use scientific notation for large numbers.

Response: We revised it. Please refer to Line 287.

Line 247: Which was generally consistent? If they are consistent, then it should be "which is consistent". There is no need to use the past sense. There are a few hotspots in the high latitudes, where they are permafrost regions, why are DOC losses relatively higher there?

Response: Thanks for your advice, we revised it, please refer to Line 289. Besides, due to the large amount of soil organic carbon stored in the permafrost zone. With global warming, the melting of the soil layer in the permafrost zone will be accompanied by the release of organic carbon, especially DOC (Li et al., 2019).

Line 252: How about a time series evaluation? For example, the DOC concentration at a large river outlet?

Response: Due to the few datasets of long time-series observations of DOC fluxes for large global rivers, we only use the annual datasets to validate the model simulations. In the future, we will collect more observations for time series evaluation.

Line 254: What do you mean by overestimated or underestimated? Compared with what? In Figure 3d, the color represents both magnitude and over/underestimate. This can be confusing. Since you have a color bar, readers will assume the color represents values based on the color bar.

Response: It is the result of comparing the simulated value with the observed value; if the simulated value is higher than the observed value it is an overestimate and the opposite is an underestimate. In addition, we added a legend to the figure as you suggest. Please see Fig.3.

Line 260: This simulation is already a global-scale DOC export study.

Response: Yes, we want to express that our developed model is reasonable.

Figure 4: The positive/negative of latent heat/sensible heat need to be checked. Also, the color bar should match the actual ranges. I am not sure why a multi-year temperature average is needed. If surface water regulation has an impact, then maybe comparing the

differences with or without regulation is more meaningful. Soil moisture cannot be negative, so the color bar needs revision. The same applies to runoff.

Response: Figure 4 shows the difference in surface hydrological variables between EXPA and CTL, indicating the effect of surface water regulation, so there exist negative values. In addition, we revised the title of the figure to make it easier for the reader to understand.

Figure 7, what is the reference of the change?

Response: In Fig. 7, the blue line is the difference between EXPA and CTL, indicating the effect of surface water regulation; the orange line is the difference between EXPB and EXPA, indicating the effect of groundwater regulation.

References

Gommet, C., Lauerwald, R., Ciais, P., Guenet, B., Zhang, H., and Regnier, P.: Spatiotemporal patterns and drivers of terrestrial dissolved organic carbon (DOC) leaching into the European river network, Earth Syst. Dynam., 13, 393–418, https://doi.org/10.5194/esd-13-393-2022, 2022.

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