Referee #1

The manuscript by Henry-Pinilla et al. presents a global model of terrestrial organic carbon (OC) routing through the inland-water network, including a simplistic representation of OC losses through burial and mineralization in rivers, lakes, reservoirs, floodplains, and coastal wetlands, including mangroves, salt marshes, and seagrass meadows (together defined as the land–ocean aquatic continuum, LOAC). The model is driven by a large number of input datasets (including published data on soil erosion rates, topsoil texture and OC content, the distribution of inland waters and wetlands, flow directions, and simulated runoff) to estimate OC burial and mineralization at an annual time step and at high spatial resolution (3.75 arcmin, approximately 7 km at the equator).

The representation of processes is very simplistic, partly borrowing from concepts developed in much older simple models (for example, Brune's 1953 concept of trapping efficiency), and relying on assumptions that are in part questionable.

We thank the referee for these insightful comments and for highlighting important aspects of the model design. Global-scale models necessarily involve simplifications, and we will clarify the rationale and implications of these choices in both the present document and the revised manuscript. However, we respectfully disagree with the characterization of the model as simplistic. Our process-based approach is parsimonious and robust, aiming to represent the dominant controls on sedimentation, mineralization, and burial at the global scale while maintaining computational feasibility. We acknowledge that some aspects of the model are better sustained by empirical evidence than others (for instance, OC burial in floodplains). Therefore, our simplified solutions are sometimes driven by a lack of robust evidence to incorporate more nuanced alternatives. We understand that this is a limitation of our modelling approach, but in any way makes our model simplistic.

Importantly, the novelty of LOAC-OCB lies in its integrative framework: to our knowledge, it is the first model to explicitly represent and connect these processes across rivers, lakes, reservoirs, floodplains, and coastal ecosystems within a single global network. Existing models typically focus on individual systems or represent these processes implicitly. It cannot be expected that a model working across the LOAC will incorporate the same degree of empirical evidence for all compartments, considering the current state of knowledge.

Within this context, we rely on well-established and widely validated formulations, such as the Brune's trapping efficiency relationship noted by the reviewer, which remain one of the most reliable empirical methods for sedimentation of particles in reservoirs, as highlighted by recent evaluations (Tan et al., 2019). Using long tested, robust empirical approaches for modelling biogeochemical processes should not be labelled as simplistic, even if they are based on straightforward principles and uncomplicated mathematical formulations. We are truly confused by the referee's comment in this respect.

Tan, G., Chen, P., Deng, J., Xu, Q., Tang, R., Feng, Z., & Yi, R. (2019). Review and improvement of conventional models for reservoir sediment trapping efficiency. Heliyon, 5(9). DOI: 10.1016/j.heliyon.2019.e02458

Moreover, in response to the referee's concerns, we substantially expanded the model evaluation framework. Specifically, we implemented a global sensitivity analysis using the Morris screening method (Morris, 1991; Campolongo et al., 2007), an efficient approach for identifying the most influential parameters in computationally demanding models. The method quantifies parameter importance through repeated perturbations across the parameter space and evaluates both their overall effects and potential interactions. To conduct this analysis, we performed approximately 17,000 model simulations, representing a substantial computational effort. This allowed us to identify the parameters exerting the strongest control on model behavior and provided a much more robust assessment of parameter sensitivity and model uncertainty. The implications of these results are discussed in the relevant responses below.

Morris, M. D. (1991). Factorial sampling plans for preliminary computational experiments. Technometrics, 33(2), 161-174. DOI: 10.1080/00401706.1991.10484804

Campolongo, F., Cariboni, J., & Saltelli, A. (2007). An effective screening design for sensitivity analysis of large models. Environmental modelling & software, 22(10), 1509-1518. DOI: 10.1016/j.envsoft.2006.10.004

After identifying the most sensitive parameters using the Morris method, we further quantified model uncertainty using a bootstrap approach (Efron, 1979; Davison et al., 2003). Specifically, we performed 1,000 model realizations by varying the most influential parameters within their plausible ranges, assuming uniform distributions. This analysis allowed us to propagate parameter uncertainty through the model and derive uncertainty estimates for the main output fluxes. This analysis also allowed us to better assess the adequacy of our model formulations for the different ecosystems along the LOAC, and provided a more candid evaluation of model limitations. These uncertainty estimates were incorporated throughout this document and the revised manuscript wherever model results are reported.

Efron, B. (1992). Bootstrap methods: another look at the jackknife. In Breakthroughs in statistics: Methodology and distribution (pp. 569-593). New York, NY: Springer New York. DOI: 10.1007/978-1-4612-4380-9_41

Davison, A. C., Hinkley, D. V., & Young, G. A. (2003). Recent developments in bootstrap methodology. Statistical Science, 141-157. https://www.jstor.org/stable/3182844

For instance, the model assumes that coastal ecosystems such as mangroves, salt marshes, and seagrass meadows receive sediments primarily from rivers, while neglecting sediment inputs from the sea driven by coastal currents and tides.

We thank the referee for this important observation. We agree that sediment accumulation in coastal vegetated ecosystems is influenced by both terrestrial and marine sediment sources. River-derived sediments constitute an important source of material for many mangroves, salt marshes, and seagrass meadows, particularly in deltaic and estuarine settings where they contribute substantially to sediment accretion (Woodroffe et al., 2016; Roner et al., 2021). However, sediments may also be supplied through tidal exchange, coastal currents, wave-driven resuspension, and sediment redistribution within coastal environments (Fagherazzi et al., 2013; Adame et al., 2010). The relative importance of these pathways varies substantially among ecosystems and regions and is not currently constrained by globally consistent datasets.

LOAC-OCB was specifically developed to represent the transport and fate of terrestrially derived POC along the LOAC. Consequently, coastal ecosystems are represented as recipients of land-derived sediment and POC fluxes, while marine-derived sediment inputs are not explicitly considered. We acknowledge that this simplification introduces uncertainty in coastal environments where sediment dynamics are strongly influenced by marine processes. We have therefore clarified this assumption in the manuscript and included it among the limitations and future development opportunities of the framework (Section 4):

"Finally, the representation of coastal environments in LOAC-OCB remains simplified. Coastal ecosystems are represented as recipients of terrestrially derived sediment and POC transported through the LOAC. While river-derived sediments are known to contribute substantially to sediment accretion in many deltaic and estuarine mangroves, salt marshes, and seagrass meadows (Woodroffe et al., 2016; Roner et al., 2021), marine-derived sediment inputs associated with tidal exchange, coastal circulation, wave-driven resuspension, and sediment redistribution are not explicitly represented (Fagherazzi et al., 2013; Adame et al., 2010)."

Woodroffe, C. D., Rogers, K., McKee, K. L., Lovelock, C. E., Mendelssohn, I. A., & Saintilan, N. (2016). Mangrove sedimentation and response to relative sea-level rise. Annual review of marine science, 8, 243-266.

Roner, M., Ghinassi, M., Finotello, A., Bertini, A., Combourieu-Nebout, N., Donnici, S., ... & D'alpaos, A. (2021). Detecting the delayed signatures of changing sediment supply in salt-marsh landscapes: the case of the Venice Lagoon (Italy). Frontiers in Marine Science, 8, 742603.

Fagherazzi, S., Wiberg, P. L., Temmerman, S., Struyf, E., Zhao, Y., & Raymond, P. A. (2013). Fluxes of water, sediments, and biogeochemical compounds in salt marshes. Ecological Processes, 2(1), 3.

Adame, M. F., Neil, D., Wright, S. F., & Lovelock, C. E. (2010). Sedimentation within and among mangrove forests along a gradient of geomorphological settings. Estuarine, Coastal and Shelf Science, 86(1), 21-30.

Similarly, it assumes that OC deposited on floodplains or other wetlands, which are periodically dry and more aerated, decomposes at rates comparable to those in permanently inundated benthic sediments, where anaerobic conditions are more likely to develop.

We agree with the referee that decomposition rates are expected to differ between permanently inundated sediments and periodically exposed floodplain sediments, particularly because exposure to oxygen during dry periods can enhance OC decomposition.

We would like to clarify, however, that LOAC-OCB does not assume identical mineralization rates across ecosystem types. Although the same first-order formulation is applied throughout the model, mineralization is controlled by ecosystem-specific conditions, particularly residence time and temperature. Because residence time is calculated differently depending on the ecosystem type, the resulting effective mineralization rates differ among them.

We nevertheless acknowledge that the current version of LOAC-OCB does not explicitly represent hydrological intermittency, drying-rewetting cycles, or redox-dependent decomposition processes. Consequently, periods during which floodplain sediments become exposed and potentially experience enhanced aerobic mineralization are not explicitly simulated. To partially mitigate this limitation, we restricted the analysis to regularly and seasonally flooded systems, which are most likely to remain connected to the aquatic continuum at the annual time scale considered by the model.

Nevertheless, intermittency is known to influence OC processing and could affect both mineralization and burial dynamics. Importantly, while intermittency is increasingly recognized as an important control on carbon processing (Catalán et al., 2023), its explicit representation remains largely absent from current global-scale carbon models.

Catalan, N., Del Campo, R., Talluto, M., Mendoza-Lera, C., Grandi, G., Bernal, S., ... & Bertuzzo, E. (2023). Pulse, shunt and storage: Hydrological contraction shapes processing and export of particulate organic matter in river networks. Ecosystems, 26, 873-892.

Addressing this limitation will require both improved global datasets and a better understanding of the associated biogeochemical processes, and would be a potential focus of future model developments.

We have now clarified this limitation in the manuscript and expanded the discussion of the implications of the steady-state representation of hydrology in the Conclusions and Future Developments section:

"Another limitation of the current framework is its steady-state representation of hydrology. Although high-flow conditions are partially considered in the floodplain component and the associated hydraulic parameters are not among the dominant controls on model outputs according to the global sensitivity analysis, LOAC-OCB does not explicitly resolve temporal hydrological variability or event-driven sediment transport. Future developments could therefore adopt a transient approach to assess the influence of floods, droughts, and other hydrological extremes on sediment and terrestrial POC dynamics along the LOAC."

Although intermittency is not explicitly represented, the model does not predict identical mineralization behavior across ecosystem types. Differences in residence time and hydrological conditions result in substantially lower median mineralization rates in floodplains than in reservoirs and coastal ecosystems (Fig. 8). This figure has also been updated to incorporate the results from the 1,000 bootstrap simulations, thereby providing an explicit representation of model uncertainty:

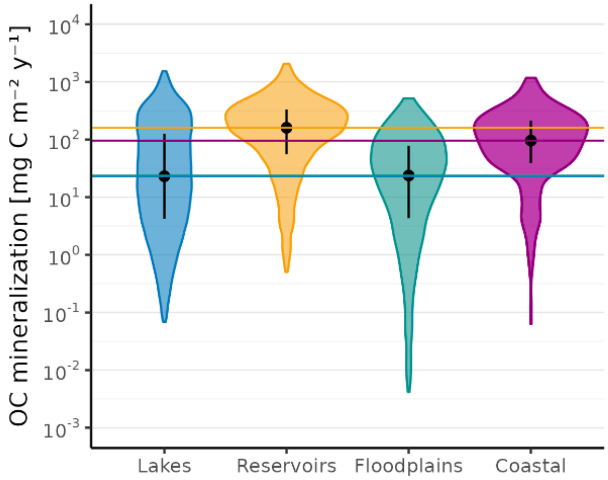


Figure 8. OC mineralization by ecosystem type. Violin plots show the distribution of ecosystem-specific mean OC mineralization rates (mg C m^{-2} d^{-1}) estimated from 1000 bootstrap simulations. The width of each violin represents the density of ecosystems at a given mineralization rate. Black vertical lines within each violin indicate the inter-quartile range (25th – 75th percentiles), with a central point marking the median value for that ecosystem type. Values outside the 1–99 percentile range were excluded to remove extreme outliers and improve visualization of the main distribution.

We have also clarified these aspects in the revised manuscript, emphasizing that the model captures first-order differences in hydrological control on mineralization, although not explicitly resolving redox-dependent decomposition processes. The addition in Section 2.3.4 reads as follows:

"The same first-order mineralization formulation is applied across all ecosystem types; however, resulting mineralization rates differ according to ecosystem-specific temperature and residence-time conditions. Hydrological intermittency, drying-rewetting cycles, and redox-dependent decomposition processes are not explicitly represented in the current version of the model."

Most importantly, the study appears to assume that gross hillslope erosion is equivalent to sediment inputs to inland waters, thereby neglecting the important role of footslopes, which intercept and store much of this material before it reaches the inland-water network.

We thank the referee for raising this important point. We agree that, at local scales, a substantial fraction of eroded material can be stored in intermediate landscape positions such as footslopes before reaching the river network.

However, we would like to clarify that the sediment input used in our model is not intended to represent gross hillslope erosion, but rather the soil loss estimated at the scale of each modelling unit (grid cell) as provided by the GloSEM (RUSLE-based) product. In this framework, soil erosion refers to the amount of sediment leaving a given cell, while areas experiencing net deposition over the long term are not explicitly represented within that cell (Borrelli et al., 2017).

Borrelli, P., Robinson, D. A., Fleischer, L. R., Lugato, E., Ballabio, C., Alewell, C., ... & Panagos, P. (2017). An assessment of the global impact of 21st century land use change on soil erosion. Nature communications, 8(1), 2013. DOI: 10.1038/s41467-017-02142-7

As described in the original dataset, the approach does not simulate explicit downslope routing and intermediate sediment storage processes. Instead, these processes are implicitly embedded within the large-scale parameterization of erosion rates rather than explicitly resolved. The underlying assumption is that, when applied consistently at appropriate spatial scales, the resulting soil loss estimates provide a meaningful approximation of sediment mobilization at regional to global scales.

We have made this explicit in Section 2.5.3 of the revised manuscript:

"Local sediment input at each node is estimated as the amount of soil displaced by water, expressed in Mg ha^{-1} y^{-1}, based on the RUSLE-based Global Soil Erosion Modeling platform (GloSEM, Borrelli et al., 2017). ***This approach does not explicitly represent intermediate sediment storage and hillslope–channel connectivity processes, which are therefore implicitly incorporated within the large-scale soil loss estimates.****"*

We are grateful to the referee for raising this point, as revisiting this aspect led us to identify an erratum in the reported global flux values. The actual sediment input from terrestrial systems to the LOAC through erosion is 34.6 Pg y^{-1}, of which 0.48 Pg y^{-1} corresponds to the OC fraction (1.39%). This erratum affects only the reported values in the manuscript and does not alter the model calculations, underlying processes, or conclusions. These values align with recent global estimates. For example, Li et al. (2022) estimated a terrestrial POC input of 0.77 Pg C y^{-1} to the LOAC, while Battin et al. (2023) reported 0.72 Pg C y^{-1} of DOC and POC exported from soils and wetlands to inland waters. Despite differences in the carbon forms represented and in the point of quantification along the terrestrial–aquatic continuum, these estimates are broadly consistent with our value of 0.48 Pg C y^{-1}.

Within this context, our model uses these sediment fluxes as inputs to the aquatic network, consistent with the intended use of the dataset. We acknowledge that this represents a simplification and that the model does not explicitly resolve hillslope–channel connectivity or sediment storage at intermediate positions. However, we think that this is an acceptable simplification for a model focused on LOAC processes and working at the global scale in a steady state condition.

We will clarify this assumption in the revised manuscript and better discuss its implications, emphasizing that the model aims to capture large-scale patterns of sediment and terrestrial OC transfer, rather than detailed hillslope-scale processes.

The limited model evaluation against observations is not very convincing and indicates underestimation of burial rates by up to two orders of magnitude, although this may partly reflect biases in the observational database. Model results are compared mainly with previous global estimates, but here I identified several misinterpretations and inappropriate comparisons.

We thank the referee for this comment. To address the concerns regarding model evaluation, we summarize below the different validation steps that were conducted and clarify how each of them contributes to assessing model performance. Clarifications were also made in Sections 3.2 and 3.5 of the revised manuscript and are highlighted below where relevant.

First, regarding sediment fluxes and discharge, the comparison against independent global datasets shows good agreement, with 94% of discharge values and 64–72% of sediment-related variables falling within one order of magnitude of observations. This level of agreement is consistent with expectations for global-scale models of this type.

Second, for burial-related variables (LSR and OCB), the comparison with the observational dataset shows that modeled and observed distributions largely overlap for reservoirs and coastal ecosystems, and follow consistent patterns across ecosystem types. While median modeled OCB values are generally lower than observational estimates, particularly in lakes and floodplains, the differences are typically within one order of magnitude rather than the two orders of magnitude suggested by the referee.

The apparent discrepancies can be explained by several factors, which are now discussed more explicitly in Section 3.2 of the revised manuscript (current L396-398). The revised text reads as follows:

“The observed distributions of LSR and OCB for reservoirs and coastal ecosystems fully overlap with the modeled distributions, showing strong agreement. For lakes, observed distributions also overlap with modeled distributions but primarily at the upper end of the range. Several factors likely contribute to these differences: (i) observational datasets are biased toward systems with high sedimentation and OC burial rates, (ii) observational estimates generally include both allochthonous and autochthonous OC whereas LOAC-OCB only represents terrestrial OC, and (iii) the exclusion of small lakes and the large spatial units used to represent floodplains tend to reduce modeled rates relative to many site-based observations. These factors are discussed in more detail below.”

Furthermore, the possibility of observational bias is supported by ecosystem types for which substantially more data are available. For example, in lakes and reservoirs, the observational dataset appears biased toward systems with high OC content and elevated burial rates, as illustrated by the concentration of observed systems within the upper range of OC contents and OCB rates relative to the much broader distribution represented by the model (Figs. A3, A4). Such a bias is expected because sediment studies are often preferentially conducted in systems known or presumed to exhibit substantial organic carbon accumulation and are therefore not necessarily representative of the global population of aquatic ecosystems. Therefore, a similar effect may also contribute to the apparent discrepancy observed for floodplains, where observational data are considerably more limited.

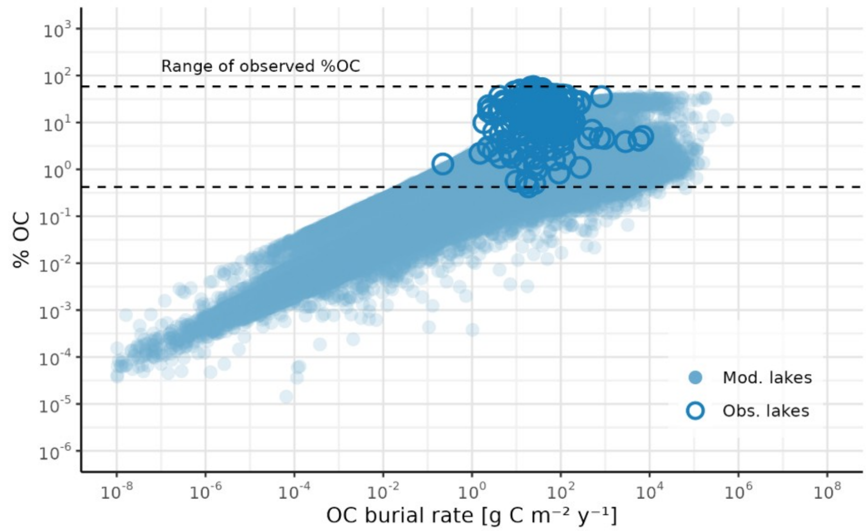


Figure A3. Scatterplot of organic carbon burial (OCB) rate versus organic carbon content (%OC) in lakes. Modeled lakes are shown as semi-transparent points, while observed lakes are shown as outlined points. The black dashed horizontal lines indicate the full range of %OC measured in observed lakes.

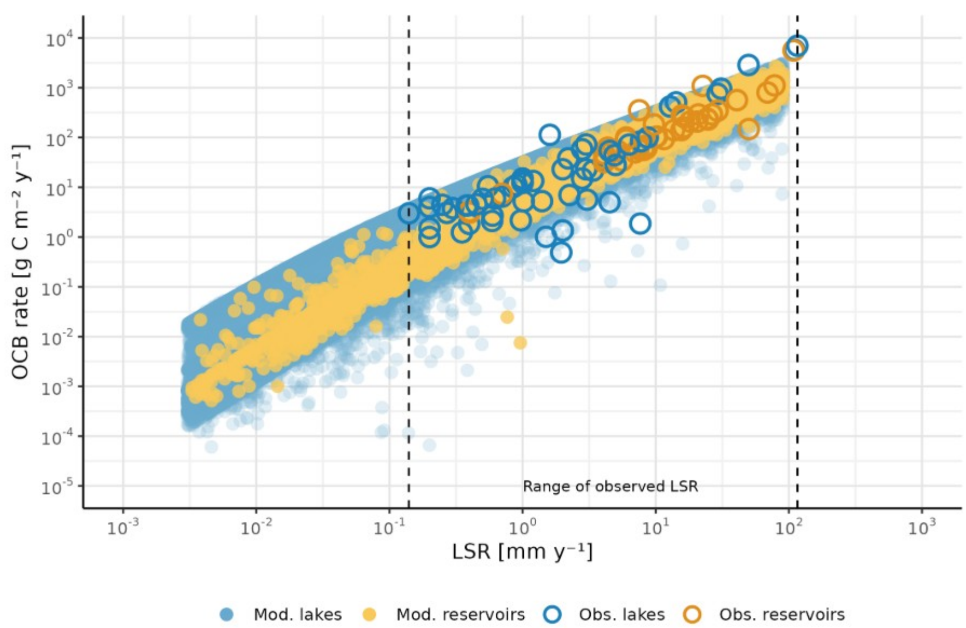


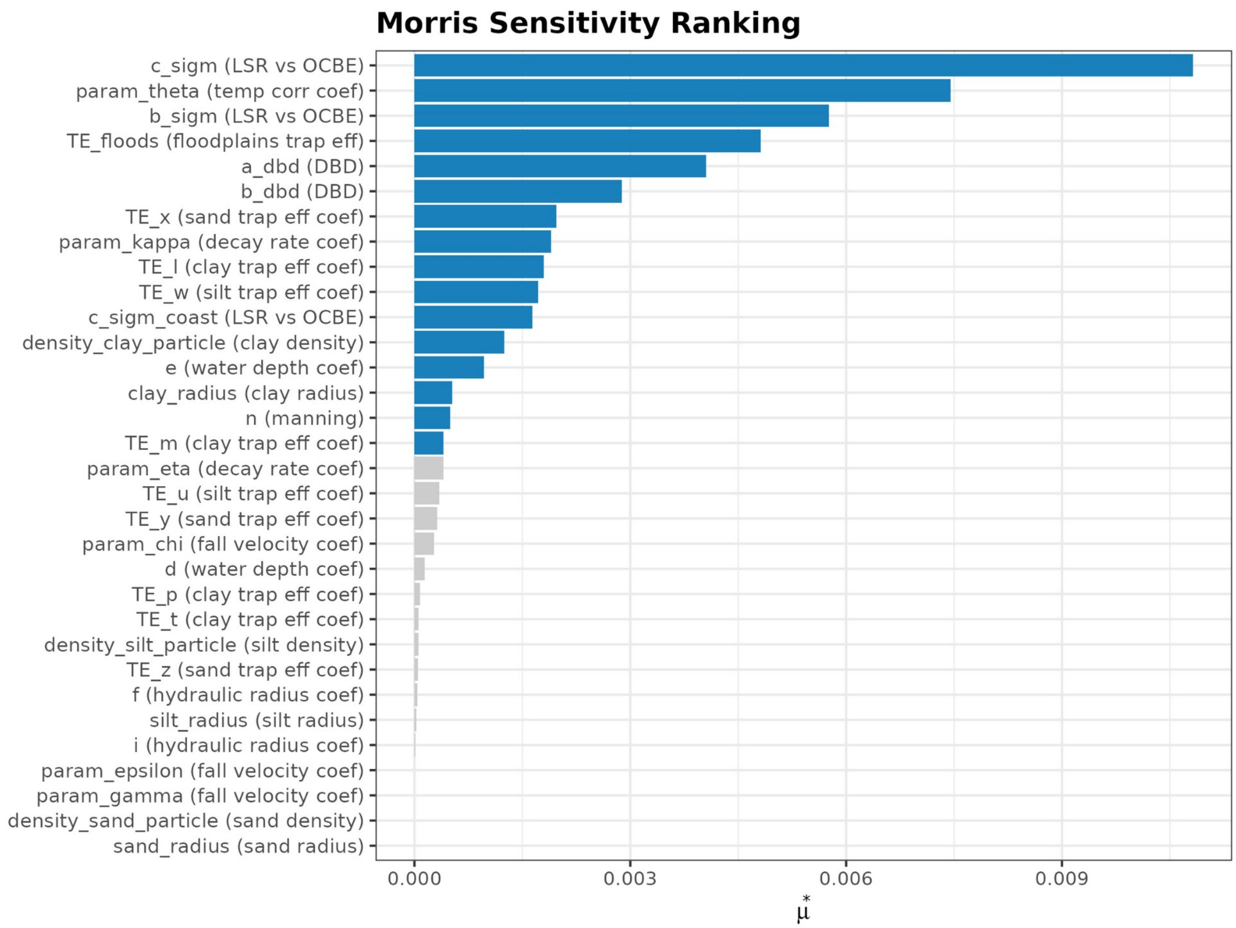
Figure A4. Relationship between linear sedimentation rate (LSR) and organic carbon burial (OCB) rate for lakes and reservoirs. Modeled data are shown as filled circles and restricted to the 5th–95th percentile range of LSR values, highlighting the central distribution of modeled conditions and minimizing the influence of extreme outliers that can obscure general trends. Observed data (open circles) are plotted in full for reference. Black dashed vertical lines indicate the observed LSR range across all lake and reservoir measurements. This percentile-based filtering focuses the analysis on the most representative range of modeled conditions while maintaining observed variability for contextual interpretation.

In particular, the largest deviations occur for floodplains, where modeled values are lower than observations. We attribute this mainly to (i) the limited amount of observational data available for these systems, which may bias the literature toward sites with particularly high sedimentation and OC burial rates; (ii) the large differences in spatial scale between modeled units and field measurements, as observational studies typically focus on relatively small depositional hotspots whereas the model represents much larger floodplain units; and (iii) the lack of a globally consistent definition of floodplain boundaries, which introduces additional uncertainty in both observed and modeled estimates. These factors are expected to increase the likelihood of observing higher LSR and OCB values in the literature than those obtained when averaging across the much larger floodplain areas represented by the model. The observed discrepancies are therefore not indicative of a systematic two-order-of-magnitude underestimation, but rather reflect differences in definitions, scale, and data availability.

We added a clarification in Section 3.2 of the revised manuscript (current L418-420):

"These large discrepancies in spatial scale between modeled units and field observations likely influence their comparability. Because field studies often target depositional hotspots, whereas LOAC-OCB represents average conditions across much larger floodplain units, such scale mismatches are expected to yield higher observed LSR and OCB values than modeled estimates. This should not be interpreted as a shortcoming of either approach but as a consequence of their intrinsic differences in scale and methodology."

Additionally, to address the referee's concerns and strengthen the evaluation framework, we performed a new global sensitivity and uncertainty analysis of the model. As briefly mentioned before, we assessed parameter sensitivity using the Morris screening method, identifying the 16 most influential parameters (out of 32). The most sensitive parameters are primarily related to sediment properties controlling transport and deposition (e.g., trapping efficiencies, particle size characteristics), as well as the parameters governing the OC burial efficiency and sedimentation relationship and mineralization rates. See the following Figure, which was also included in the new Section 3.6: "Sensitivity analysis and uncertainty quantification" of the revised manuscript:



Uncertainty in model outputs was subsequently quantified through the uncertainty analysis described above, based on 1,000 model realizations using the 16 most influential parameters identified by the Morris screening. Results are reported as medians ± standard deviations and will be incorporated throughout the revised manuscript. For global terrestrial POC burial, the estimated flux is 0.243 ± 0.012 Pg C yr^{-1}, corresponding to a coefficient of variation of 0.051, which indicates relatively low uncertainty associated with parameter variability. Across ecosystem types, median terrestrial POC burial fluxes are estimated at 0.050 ± 0.003 Pg C yr^{-1} in lakes, 0.070 ± 0.004 Pg C yr^{-1} in reservoirs, 0.093 ± 0.010 Pg C yr^{-1} in floodplains, and 0.029 ± 0.003 Pg C yr^{-1} in coastal ecosystems. The corresponding global estimates for terrestrial POC mineralization and export to the ocean are 0.166 ± 0.014 Pg C yr^{-1} and 0.076 ± 0.004 Pg C yr^{-1}, respectively. These results suggest that the principal conclusions of the model are robust to the uncertainty associated with the most influential parameters. Furthermore, these estimates are consistent with previous global assessments, as demonstrated in the substantially revised Section 3.5. Revising this section in response to the referee's comments led us to identify an erratum in the global flux values reported in the manuscript and Table 2. This erratum affected only the reported values and did not affect the model calculations, which were free from this error.

We also agree that Drake et al. (2018) is no longer the most appropriate reference for some of these comparisons. In the revised manuscript, we expanded the comparative analysis by incorporating additional relevant studies, including Battin et al. (2023), Beusen et al. (2005), and Tian et al. (2026). The publication of this latter study earlier this month further highlights that quantifying terrestrial POC fluxes at global scales remains at the forefront of current carbon-cycle research, reinforcing the need for integrative modeling frameworks capable of tracking the fate of this carbon across the entire LOAC. Furthermore, we revised Table 2 to include the corrected fluxes and explicitly indicate the carbon pools and sources of carbon represented in each study. This will help clarify which estimates are directly comparable and which differences arise from contrasting definitions, carbon forms, or ecosystem type coverage, thereby reducing potential misinterpretations.

Beusen, A. H. W., Dekkers, A. L. M., Bouwman, A. F., Ludwig, W., & Harrison, J. (2005). Estimation of global river transport of sediments and associated particulate C, N, and P. Global Biogeochemical Cycles, 19(4). DOI:10.1029/2005GB002453

Tian, S., Li, D., Regnier, P., Dean, J. F., Syvitski, J., Feng, M., ... & Ni, J. (2026). Rapid changes in global river particulate organic carbon flux. Nature Geoscience, 1-7. 10.1038/s41561-026-02034-w

The revised Section 3.5, including Table 2 is the following:

3.5 Global OC fluxes

When scaled to their total modeled surface areas, estimated global median OCB fluxes were 0.093 ± 0.010 Pg C y-1 for floodplains (8,363,169 km2), 0.070 ± 0.004 Pg C y-1 for reservoirs (253,404 km2), 0.050 ± 0.003 Pg C y-1 for lakes (2,061,552 km2), and 0.029 ± 0.003 Pg C y-1 in coastal ecosystems (873,923 km2). This yields a LOAC contribution of 0.243 ± 0.012 Pg C y-1 to the global OCB budget, highlighting the major role of floodplains, driven largely by their extensive spatial coverage despite relatively low areal OCB rates. Reservoirs, in contrast, represent a much smaller surface area and contribute disproportionately to global OCB due to their high sediment trapping efficiency and LSR. Overall, we estimated that the LOAC receives 34.55 Pg y-1 of sediment from the terrestrial systems through erosion, with the OC fraction corresponding to 0.482 Pg C y-1 (1.39%). Of this terrestrial POC load, 0.243 ± 0.012 Pg C y-1 is buried within the sediments, 0.166 ± 0.014 Pg C y-1 is mineralized, and 0.076 ± 0.004 Pg C y-1 is exported to the open ocean.

Many studies have reported global OCB estimates (Table 2), and most are broadly consistent with our assessment. Direct comparisons should nevertheless be interpreted with caution, as global studies often differ in the C pools considered and in the aquatic ecosystems included. A study that is particularly comparable to ours is Li et al. (2022), given the similarity in methodology and the OC sources and pools considered. They estimated a higher terrestrial POC input to the LOAC of 0.77 Pg C y-1. In comparison, Battin et al. (2023) estimated that soils and wetlands export 0.72 Pg C y-1 to the river network, a value lower than that reported by Li et al. (2022) but higher than our estimate of terrestrial POC input to the LOAC (0.48 Pg C y-1). However, their estimate includes both DOC and POC and represents C fluxes after passage through wetlands. They also estimated an export of 0.43 Pg C y-1 to the coastal ocean, whereas our estimate reflects the residual flux after accounting for burial and processing within coastal blue-carbon ecosystems. Similarly, Li et al. (2022) estimated a land-to-ocean POC export of 0.29 Pg C y-1, although their framework does not explicitly consider the role of floodplains and coastal ecosystems. Other comparable export estimates, which approximate even better with ours, were reported by

Beusen et al. (2005), Liu et al. (2024) and Tian et al. (2026), who estimated that 0.2, 0.18, and 0.17 Pg C y-1 of terrestrial POC, respectively, but, again, this is the export that reaches the coastal ocean. Likewise, Regnier et al. (2022) estimated that inland waters, estuaries, and tidal wetlands collectively bury 0.25 ± 0.15 Pg C y-1, remarkably close to our estimate of total OCB across the LOAC. Their study, however, represented the broader aquatic carbon cycle and therefore included additional carbon pools such as dissolved organic carbon (DOC) and dissolved inorganic carbon (DIC). Consequently, they reported higher terrestrial carbon inputs (2.95 ± 0.55 Pg C y-1) and substantially greater mineralization fluxes (1.85 ± 0.50 Pg C y-1) than those estimated here. Despite these methodological differences, the overall agreement among studies supports the robustness of our estimates and suggests that LOAC-OCB captures the dominant controls on the transport, processing, and long-term burial of terrestrial organic carbon along the aquatic continuum.

Table 2. Global median terrestrial particulate organic carbon (POC) fluxes (Pg C y^{-1} ± SD) across LOAC ecosystems and comparison with previous studies. DIC: dissolved inorganic carbon; DOC: dissolved organic carbon; TC: total carbon; TOC: total organic carbon; allo: allochthonous; auto: autochthonous. (*) None of these studies accounts for burial and processing within coastal blue-carbon ecosystems. (**) The study is included for reference only, as it accounts for mineral-soil wetlands and boreal peatlands rather than riverine floodplains.

OC flux	LOAC-OCB	Other studies	C pool (source)	Reference
OC input to LOAC	0.482	0.72	DOC, POC (allo)	Battin et al. (2023)
		0.77	POC (allo)	Li et al. (2022)
		2.95 ± 0.55	DIC, DOC, POC (allo)	Regnier et al. (2022)
OC export to ocean*	0.076 ± 0.004	0.17	POC (allo)	Tian et al. (2026)
		0.18	POC (allo)	Liu et al. (2024)
		0.20	POC (allo)	Beusen et al. (2005)
		0.29	POC (allo)	Li et al. (2022)
		0.43	POC (allo)	Battin et al. (2023)
OCB LOAC	0.243 ± 0.012	0.25 ± 0.15	DIC, DOC, POC (allo)	Regnier et al. (2022)
OCB lakes	0.050 ± 0.003	0.09	TOC (allo)	Mendonça et al. (2017)
OCB reservoirs	0.070 ± 0.004	0.06	TOC (allo)	Mendonça et al. (2017)
		0.35	POC (allo)	Li et al. (2022)
OCB floodplains**	0.093 ± 0.010	0.096	TC (allo)	Bridgham et al. (2014)
OCB coastal ecosystems	0.029 ± 0.003	0.03 - 0.07	DOC, POC (allo, auto)	Lovelock and Reef (2020)
		0.07 - 0.22	DOC, POC (allo, auto)	Duarte et al. (2013); Ward et al. (2020)
		0.079 - 0.089	DOC, POC (allo, auto)	Breithaupt and Steinmuller (2022); Wang et al. (2021); Arias-Ortiz et al. (2026)
OC mineralization	0.166 ± 0.014	0.02	POC (allo)	Li et al. (2022)
		0.8 - 1.2	DOC, POC (allo)	Lal (2003)
		1.85 ± 0.5	DIC, DOC, POC (allo)	Regnier et al. (2022)

For reservoirs, Li et al. (2022) estimated, using a process-based model, that 0.35 Pg C y-1 of terrestrial POC is trapped in reservoirs, approximately five times higher than our estimate of 0.07 ± 0.004 Pg C y-1. This discrepancy is particularly noteworthy given that their estimated sediment input to reservoirs (22.8 Pg y-1) is lower than ours (34.6 Pg y-1). In *contrast, our estimate is more consistent with other global assessments. For example, Mendonça et al. (2017) reported a global reservoir OCB flux of 0.06 Pg C y-1, very close to the value obtained in this study. The agreement between these independent estimates suggests that the lower reservoir burial flux predicted by LOAC-OCB is within the range supported by current empirical evidence.*

To our knowledge, floodplains have not been explicitly represented in previous long-term OCB modelling frameworks (Hoffmann et al., 2013), limiting direct comparisons with existing studies. One of the few relevant estimates is that of Bridgham et al. (2014), who revised the global C sequestration potential of wetlands originally reported by Mitsch et al. (2013) and obtained a value of 0.096 Pg C y-1. Notably, this estimate is remarkably close to our floodplain OCB flux (0.093 ± 0.010 Pg C y-1). However, their study included a broad range of wetland types, such as mineral-soil wetlands and boreal peatlands, treated as part of the terrestrial system, making it difficult to evaluate the degree of overlap with the floodplain systems represented in LOAC-OCB.

The absence of comparable global estimates highlights a major knowledge gap in current large-scale carbon assessments. One of the main goals of LOAC-OCB is therefore to provide a simple, process-based framework that explicitly incorporates floodplains into Earth System models and global carbon budgets. While we acknowledge the scarcity of global observations available for model validation, the agreement between our estimates and independent studies, together with the successful validation of the underlying hydrological and sedimentary processes, suggests that the framework provides a promising first-order approximation of floodplain OC burial at the global scale.

Finally, estimates of OCB in coastal ecosystems vary widely across studies. Lovelock and Reef (2020) reported a global burial flux of 0.03-0.07 Pg C y^{-1} in blue-carbon ecosystems, whereas Duarte et al. (2013) and Ward et al. (2020) estimated values ranging from 0.07 to 0.22 Pg C y^{-1}. Our estimate of 0.029 ± 0.003 Pg C y^{-1} lies at the lower end of these ranges. Other studies have also reported global estimates for mangroves (0.02 Pg C y^{-1}; Breithaupt and Steinmuller, 2022), saltmarshes (0.053 Pg C y^{-1}; Wang et al., 2021), and seagrasses (0.006 - 0.016 Pg C y^{-1}; Arias-Ortiz et al., 2026), which together amount to 0.079-0.089 Pg C y^{-1}. However, these estimates are not directly comparable because they represent total OC burial (i.e., DOC and POC) and generally do not distinguish between allochthonous and autochthonous sources of OC, whereas our estimate only accounts for terrestrially derived POC transported through the LOAC. The relative contribution of autochthonous biomass to long-term burial remains poorly constrained (Li et al., 2022). In many cases, autochthonous OC is expected to be more labile than terrestrially derived particulate OC, although exceptions exist, such as lignified plant materials. Consequently, a larger fraction of autochthonous OC may be degraded before long-term burial. The terrestrial POC flux represented in LOAC-OCB may therefore constitute a substantial fraction of the persistent OC ultimately buried within coastal blue-carbon ecosystems.

Global median POC mineralization fluxes were estimated at 0.166 ± 0.014 Pg C y-1, partitioned as follows: 0.104 ± 0.007 Pg C y-1 in floodplains, 0.020 ± 0.002 Pg C y-1 in lakes, 0.017 ± 0.010 Pg C y-1 in rivers, 0.012 ± 0.003 Pg C y-1 in reservoirs, and 0.010 ± 0.001 Pg C y-1 in coastal ecosystems.

As discussed in Section 3.4, direct comparisons between these estimates and the literature are challenging because most observational studies report total CO2 and CH4 emissions, which integrate multiple carbon sources, including autochthonous production, DOC mineralization, and terrestrial OC inputs. For example, Li et al. (2022) estimated that 0.02 Pg C y-1 of terrestrial POC is transformed into DOC, DIC, CO2, and CH4 along the LOAC, although they do not explicitly consider the role of floodplains and coastal ecosystems. Likewise, Lal (2003) estimated that 0.8 - 1.2 Pg C y-1 of terrestrial OC is emitted to the atmosphere due to lateral transport induced by erosion, a value substantially greater than our estimate, although the two quantities are not directly comparable because their assessment includes both dissolved and particulate terrestrial OC and does not account for within-system processing. Similarly, Regnier et al. (2022) estimated atmospheric emissions of 1.85 ± 0.5 Pg C y-1 from inland waters, although this figure also includes inorganic carbon pathways involving DIC.

The lower mineralization fluxes simulated by LOAC-OCB are therefore expected. First, the model does not represent inorganic carbon emissions, which are known to contribute substantially to global aquatic C fluxes (Marcé et al., 2015). Second, it exclusively tracks the mineralization of terrestrially derived POC, excluding autochthonous organic matter. Because autochthonous OC is generally more labile than terrestrial POC, it is more susceptible to degradation and can contribute disproportionately to aquatic CO2 and CH4 emissions. This distinction is particularly relevant in natural lakes, where autochthonous production represents an important fraction of total OC inputs (Fig. A5). Consequently, our estimates should be interpreted as atmospheric emissions associated with terrestrially derived particulate OC rather than total carbon emissions from aquatic ecosystems.

Overall, I find the model too simplistic and insufficiently evaluated against observations for this to be an acceptable model development or model evaluation study. I recognize that, given the limited observational data and the complexity of the underlying processes, developing a robust model for these dynamics is extremely challenging. I can accept that a simplistic conceptual model such as the one presented here could serve as a basis for re-evaluating and discussing the importance of OC burial in inland waters and associated wetlands at the global scale. However, that would make it better suited to a journal such as ESD or Biogeosciences rather than GMD. Even for such a venue, however, both the study and the manuscript would require substantial revision. While I therefore have to recommend rejection of the manuscript for GMD, I provide some comments below that may help improve it for submission to another journal with a less specific focus on model development.

We thank the referee for this overall assessment and for acknowledging the challenges associated with modeling these processes at the global scale.

As discussed in our initial response to the referee, we respectfully disagree with the characterization of the model as simplistic. We accepted the criticism regarding the limited evaluation of the model and consequently made a substantial effort to strengthen this aspect of the manuscript, including weeks of computation on a high-performance computing cluster. As detailed in our responses above, LOAC-OCB adopts a parsimonious but process-based approach, using established formulations to represent the dominant controls on sedimentation, mineralization, and burial at the global scale. While simplifications are unavoidable in an Earth-system-scale framework, we believe they are well justified and appropriate for the questions addressed by the model.

We nevertheless greatly appreciate the constructive nature of the referee's comments, which have led to substantial improvements in the revised manuscript. We have substantially strengthened the evaluation framework through a global sensitivity analysis (~17,000 simulations) and an uncertainty analysis (1,000 realizations), providing a more robust assessment of model behavior and uncertainty. The resulting uncertainty estimates are now reported throughout the manuscript and provide an explicit assessment of the confidence that can be placed in the resulting estimates. We have substantially expanded and refined our comparison with other global assessments, and we have better clarified and justified model assumptions, methodology, and limitations.

We would like to highlight that the main contribution of LOAC-OCB is its integrative modeling framework, which explicitly links rivers, lakes, reservoirs, floodplains, and coastal ecosystems within a single global network. As reviewed in Henry et al. (2024), existing global models of carbon transport and burial generally rely on parsimonious representations of large-scale processes while necessarily simplifying many of the underlying mechanisms. However, none of the modeling frameworks reviewed therein explicitly represents terrestrial OC burial across the major components of the LOAC while simultaneously accounting for upstream–downstream interactions among ecosystem types. We therefore consider that the development, implementation, and evaluation of LOAC-OCB constitute a relevant contribution to the model-development community and are well aligned with the scope of GMD. We therefore believe that the revised manuscript now provides both the model development and the quantitative evaluation expected of a contribution to GMD.

Henry, D., Catalan, N., Obrador, B., & Marce, R. (2024). Modeling carbon burial along the land to ocean aquatic continuum: Current status, challenges and perspectives. Earth-Science Reviews, 253, 104791. DOI: 10.1016/j.earscirev.2024.104791

Below, we address the specific comments individually.

L7: Maybe it's better to report the resolution in arc-minutes and to give the approximate size in km in brackets.

We agree that this would improve clarity and have replaced 0.0625 x 0.0625 with 3.75 arcmin (~ 7 km at the equator) throughout the manuscript.

L11-12: Please, report uncertainties for all numbers that you report as your results.

We agree that including uncertainty estimates substantially strengthens the robustness and interpretability of the results. Addressing this comment required a substantial expansion of the evaluation framework, including a global sensitivity analysis (~17,000 simulations) and a parameter uncertainty analysis (1,000 model realizations). These analyses enabled us to quantify and propagate model uncertainty into the main output fluxes. Consequently, uncertainty estimates are now reported throughout the revised manuscript and accompany all major model results.

L22-24: Drake et al.'s budget doesn't account for burial in coastal sediments nor in floodplains. Also, only a non-determined fraction of these terrestrial carbon inputs is in form of OC. Following Battin et al. (2023), a major proportion of these carbon inputs may be inorganic carbon (IC). Moreover, this value of 5.1 Pg C/yr represents an upper bound estimate, which is based on an erroneous CO_2 emission estimate from the lower Amazon river by Sawakuchi et al. (2017) that has since then been corrected with an erratum (estimate of CO_2 emission from lower Amazon revised downward by a factor of 10). To my knowledge, the Drake et al. study has not been revised after that.

Drake et al. also report a flux of carbon to the coast, on which their budget calculation of terrestrial carbon inputs is based. To make a consistent estimate of the C lost in the LOAC, you should use that value instead the independent estimate by Liu et al.. In addition, note that Liu et al. also report the amount of dissolved and particulate OC exported to the coast. Finally, the fluvial exports reported in Liu et al. and Drake et al. are exports to the coast, while coastal ecosystems follow downstream in the LOAC.

Battin et al., 2023, https://doi.org/10.1038/s41586-022-05500-8

Sawakuchi et al., 2017, https://doi.org/10.3389/fmars.2017.00076

We thank the referee for these valuable clarifications regarding Drake et al. (2018) and related studies. We agree that differences in scope, ecosystem coverage, and carbon pools represented need to be explicitly considered when comparing global carbon budgets.

As discussed in our previous responses, we substantially revised Section 3.5 and Table 2. The revised comparison incorporates additional recent studies and explicitly identifies the carbon pools, carbon sources, and ecosystem types represented by each estimate, thereby improving the transparency and comparability of the assessment and avoiding the limitations highlighted by the referee.

L36: Why would DOC settle? It would first need to adsorb or flocculate and so become POC, before it could settle!

We agree with the referee. This is precisely the point we aimed to convey, namely that DOC does not settle directly, but may contribute to sedimentation only after transformation into particulate forms through processes such as flocculation or adsorption onto mineral particles. We have revised the wording to make this distinction clearer and avoid potential ambiguity:

"Moreover, due to its greater size and density, POC is more likely to settle than DOC. Although DOC does not settle directly, it may contribute to sedimentation after flocculation or adsorption onto mineral surfaces, thereby becoming associated with particulate material. Nevertheless, terrestrial POC is intrinsically more susceptible to sedimentation (Li et al., 2024)."

L38: Here you should explain a bit what allochthonous and autochthonous POC represent. I guess it should be POC here, instead of simply OC.

We agree that this clarification would improve readability. While the concepts of allochthonous (terrestrial) and autochthonous (in situ produced) OC are introduced in the preceding paragraph, we now make this distinction more explicit at this point in the text and refer specifically to POC where appropriate. The revised sentence reads:

“Combined with its lower reactivity relative to autochthonous POC produced within the aquatic ecosystem, this makes allochthonous (terrestrial) POC a dominant contributor to organic carbon burial (OCB) in depositional environments (Gudasz et al., 2017).”

L60: There would also be ORCHIDEE-Clateral that also represents POC transport, burial and mineralization. Zhang et al., 2022,

https://doi.org/10.1038/s43247-022-00575-7

We thank the referee for this suggestion. We agree that ORCHIDEE-Clateral (Zhang et al., 2022) should have been included in this discussion. In fact, ORCHIDEE-Clateral is a more relevant point of comparison than ORCHILEAK because it explicitly represents the transport of sediment, POC, DOC and CO_2 through river networks, including deposition in river channels and floodplains as well as organic carbon decomposition during transport. We have therefore revised the Introduction by replacing the discussion of ORCHILEAK with ORCHIDEE-Clateral. Nevertheless, while ORCHIDEE-Clateral represents a major advance in the representation of lateral carbon transport and depositional processes, it was developed and evaluated at the European scale and does not explicitly represent lakes, reservoirs, or coastal ecosystems, nor the exchange of carbon among all major components of the land-ocean aquatic continuum. We have revised the text accordingly:

“ORCHIDEE-Clateral (Zhang et al., 2022) represents the transport of sediment, POC, DOC and CO2 through river networks, including deposition in river channels and floodplains and the decomposition of OC during transport. However, its application has been limited to Europe and it does not explicitly represent lakes, reservoirs, coastal ecosystems, nor the cascading transfer of C across all major LOAC ecosystem types.”

L64 : POM should be POC, POM was not defined.

We thank the referee for pointing this out. The use of POM in this sentence follows the terminology adopted in the original study (Druon et al., 2010), which explicitly refers to particulate organic matter (POM). We agree that the acronym was not previously defined and may therefore cause confusion. We have revised the text to define POM at first mention while preserving the terminology used in the cited study.

L84-85: The mobilization of terrestrial POC into the inland water network is the most critical part. It would be easier for the reader if you could start with that.

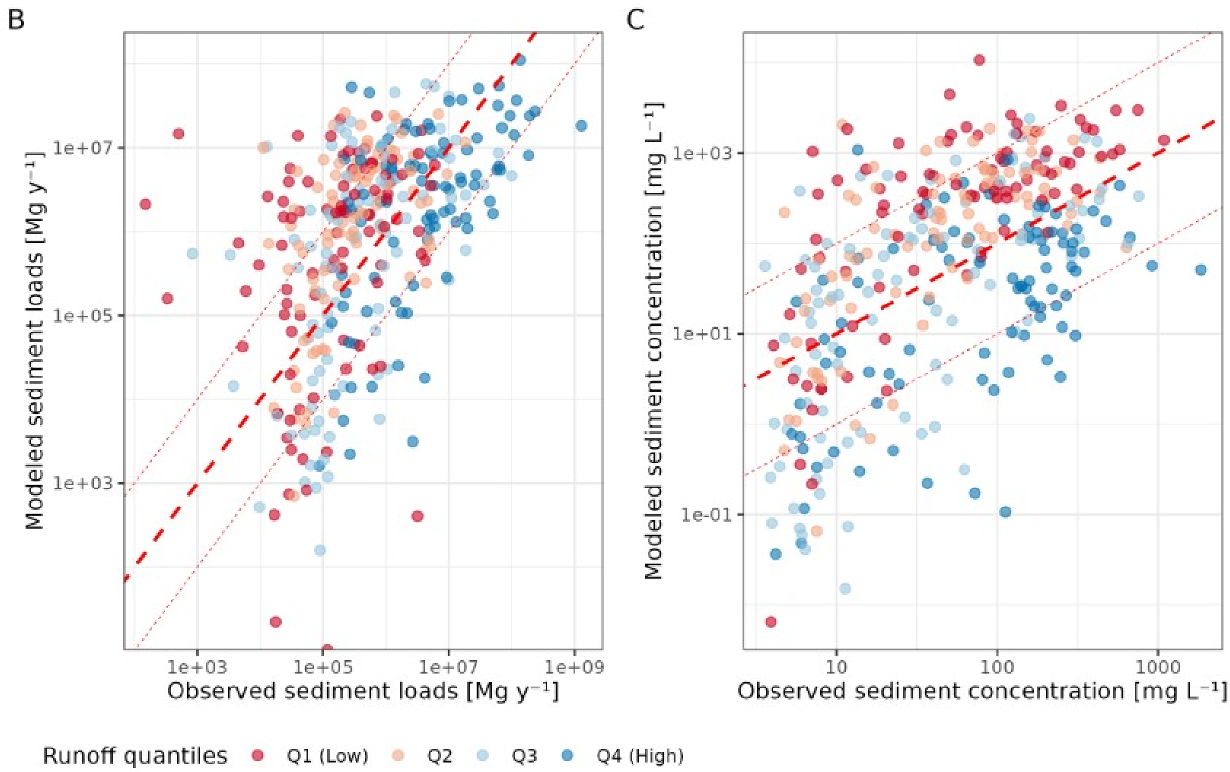
We thank the referee for this insightful comment. We agree that introducing the conceptual basis of terrestrial POC mobilization earlier in the model description improves readability and helps guide the reader through the subsequent methodological details. In the revised manuscript, we added a short conceptual overview at the beginning of Section 2.1 describing the generation, transport, processing, and fate of terrestrial POC along the LOAC before introducing the technical implementation of the model.

The new text reads:

"LOAC-OCB simulates the mobilization, transport, processing, and burial of terrestrial POC along the LOAC. Briefly, terrestrial POC is estimated at each model node from erosion-induced sediment fluxes and the OC content of the source soils. This terrestrial POC enters the river network and is transported downstream together with the mobilized sediments. Along the aquatic continuum, POC may be mineralized, deposited, buried within sediments, or exported to downstream ecosystems. The relative importance of these pathways is controlled by hydrological connectivity, water residence time, sediment retention, and burial efficiency, allowing the model to quantify the fate of terrestrial POC across rivers, lakes, reservoirs, floodplains, and coastal ecosystems within a unified framework."

Even if you can reproduce the fluvial export to the coast, given that you don't have good observational data to really validate predicted burial and mineralization, a too high or too low mobilization of terrestrial OC will simply be counterbalanced by an over- or underestimation of burial and/or mineralization.

We acknowledge that the validation of OC burial and mineralization is constrained by the limited availability of observational data at global scales, and therefore these processes are mainly evaluated against ranges of reported values. However, sediment mobilization, and consequently terrestrial POC transport, is directly evaluated through comparisons of sediment fluxes and export to the coast, which show good agreement with a robust and independent dataset (see Fig. 5).



The comparison between modeled and observed sediment loads and concentrations also indicates that the model reproduces the main large-scale patterns of sediment transport despite the expected uncertainties associated with global applications. Moreover, we can now compare our results against the recent satellite-constrained estimate of terrestrial POC export to the oceans reported by Tian et al. (2026). Their estimate of 0.17 Pg C y^{-1}, derived from remote sensing observations, compares favorably with our process-based estimate of 0.08 Pg C y^{-1}. While differences are expected given the contrasting methodologies and definitions employed, this agreement provides additional confidence that the magnitude of terrestrial POC mobilization and transfer through the LOAC is being realistically represented by the model.

L86: Mean runoff is not adequate for sediment transport. It would be good if you could include some high flows in your modelling framework, maybe represented by some upper percentile.

We agree that mean runoff does not explicitly represent high- or low-flow events and that such events can be particularly important for sediment transport. However, LOAC-OCB is a steady-state model designed to represent long-term average fluxes, and therefore the use of mean runoff is consistent with the temporal scale of the model. Replacing mean runoff with a high-flow percentile would introduce a different bias and would no longer represent average annual conditions.

Nevertheless, we acknowledge the importance of high-flow events for sediment dynamics and partially account for them in the representation of floodplains. Specifically, floodplain depth is estimated from the difference between maximum and mean discharge conditions, thereby incorporating the influence of overbank flows. To clarify this point, we revised the corresponding section of the manuscript as follows (current L208–211):

“For floodplains, the depth used in model calculations corresponds to the difference in depth between maximum and mean discharge conditions, both estimated using Eq. 5. Given the absence of globally consistent floodplain water-level observations, floodplain inundation depth is approximated as the additional water depth occurring under high-flow conditions relative to average-flow conditions. This simplified representation provides a representative inundation depth, as LOAC-OCB operates at annual timescales and does not explicitly simulate transient flood dynamics.”

More generally, we agree that an explicit representation of hydrological variability and event-driven sediment transport would constitute an important future improvement of the framework. Such a development would require moving beyond the current steady-state implementation toward a transient modeling approach capable of resolving temporal variations in discharge, sediment transport, and floodplain connectivity. We now discuss this limitation and its implications in the “Conclusions and Future Developments” section of the revised manuscript:

"Another limitation of the current framework is its steady-state representation of hydrology. Although high-flow conditions are partially considered in the floodplain component and the associated hydraulic parameters are not among the dominant controls on model outputs according to the global sensitivity analysis, LOAC-OCB does not explicitly resolve temporal hydrological variability or event-driven sediment transport. Future developments could therefore adopt a transient approach to assess the influence of floods, droughts, and other hydrological extremes on sediment and terrestrial POC dynamics along the LOAC."

L89: Here maybe list again which kind of systems that includes. I don’t understand why you don’t include estuaries (incl. deltas and fjords) where a lot of carbon can be buried below the water surface, fed by riverine inputs.

We agree that repeating the list of ecosystem types here would improve clarity and we revised the text accordingly.

We also agree that estuaries, including many deltas and fjords, can represent important sites of terrestrial POC burial. Their omission from the current version of LOAC-OCB is primarily due to the lack of globally consistent datasets describing their distribution, extent, and relevant physical characteristics at the spatial scale required by the model. As a result, their explicit representation remains challenging in a global modeling framework.

We acknowledge that this limitation may affect the allocation of terrestrial POC burial among ecosystem types. In the current implementation, the terrestrial POC that would be retained in these environments is likely assigned to downstream ecosystem compartments or exported to the ocean. We also emphasized this limitation more clearly in the “Conclusions and Future Developments” section of the revised manuscript and identified the explicit representation of estuaries, deltas, and fjords as a priority for future model developments as suitable global datasets become available:

“In addition, the current version of LOAC-OCB does not explicitly represent other important depositional environments such as estuaries, deltas, and fjords, which can constitute significant sinks for terrestrial POC \citep{Rosentreter2023,Delaune2018,smith2015}. These simplifications are primarily due to the lack of globally consistent datasets describing coastal sediment pathways, ecosystem connectivity, and physical characteristics at the spatial scale required by the model. Developing the capacity to incorporate these processes and environments should therefore be considered a priority for future versions of the framework, enabling a more complete representation of C processing and burial along the LOAC.”

L101: I know it comes much later in your MS, but as a reader I really want to know at this point how sediment generation is quantified. This is the most critical point, and in fact not trivial to do.

We thank the referee for this comment. We agree that sediment generation and the associated mobilization of terrestrial POC are among the key components of the framework and deserve an earlier introduction in the manuscript. While the detailed methodology is presented later in the manuscript (Section 2.3.1), we have added a brief description in Section 2.1 to clarify that sediment generation is estimated from a spatially explicit global soil erosion product and that the associated terrestrial POC load is derived from the organic carbon content of the eroded soils. We believe this addition improves the conceptual understanding of the model before the detailed process descriptions are introduced:

“LOAC-OCB requires a range of input data provided as global raster maps. These include terrain characteristics (e.g., slope and flow direction), hydrological variables (e.g., runoff), and ecosystem properties (e.g., area, volume, depth and water temperature), sediment generation from soils, and soil properties such as OC content and the proportion of clay, silt and sand, as we assumed the generated sediments to conserve those properties from the original soils. ***Sediment generation is estimated from spatially explicit soil erosion***

***rates, while the associated terrestrial POC load is derived from the OC content of the source soils.** A complete list of inputs is provided in Table 1 and further detailed in Section 2.5."*

L102: Other studies suggest enrichment factors, as erosion removes preferentially finer soil textures and organic carbon (check: https://doi.org/10.1016/j.geosus.2025.100328)

We thank the referee for bringing this recent study to our attention. The suggested approach is indeed interesting and highlights an important source of uncertainty when estimating the OC content of mobilized sediments. In the current version of LOAC-OCB, we assume that the OC content of mobilized sediments is equal to the OC content of the source soils. We acknowledge that alternative approaches apply enrichment factors to account for potential differences between soil OC content and the OC content of the exported sediment fraction.

However, there is currently no consensus regarding a globally applicable enrichment factor, and different studies have proposed contrasting values and approaches. For example, the study suggested by the referee proposes an enrichment factor of 0.855, implying that the OC content of mobilized sediments is lower than that of the source soils. In contrast, comparable large-scale studies such as Li et al. (2022) apply enrichment factors ranging from 1.3 to 2.6, implying enriched OC contents in the exported sediment fraction. This illustrates the lack of consensus regarding the magnitude and even the direction of sediment OC enrichment at large scales. For this first version of LOAC-OCB, we therefore opted for the more direct assumption that the OC content of mobilized sediments reflects the OC content of the source soils, avoiding the introduction of an additional parameter that remains poorly constrained at the global scale.

To evaluate the potential impact of the approach suggested by the referee, we performed a simple calculation by applying the enrichment factor of 0.855 proposed in the cited study. Applying this factor would reduce our estimated terrestrial POC input to the LOAC from 0.482 Pg C y^{-1} to approximately 0.41 Pg C y^{-1},corresponding to a reduction in the mean OC content of mobilized sediments from 1.39% to 1.19%. While this difference is not negligible, it does not substantially alter the model conclusions or the relative importance of the different LOAC components. We therefore consider the current implementation to be a reasonable global-scale approximation for this version of the model.

Furthermore, recent syntheses such as Battin et al. (2023) estimate total OC inputs to inland waters of approximately 0.72 Pg C y^{-1} when both dissolved and particulate fractions are considered. Given that LOAC-OCB simulates only terrestrial POC, our estimate does not suggest an unrealistic overestimation of terrestrial OC mobilization at the global scale. Combined with the fact that the enrichment-factor correction remains smaller than the uncertainty associated with the most influential model parameters, we consider that this assumption is unlikely to materially affect the main conclusions of the study.

L112: "water, sediment and POC"

We thank the referee for pointing this out. We unintentionally omitted POC from the description and have corrected the text accordingly in the revised manuscript.

L115: Please define riverine and palustrine wetlands! I guess some palustrine wetlands are unlikely to receive sediments (bogs and fens).

We thank the referee for this comment. In this context, the terms riverine and palustrine follow the classification used in the GLWD dataset, which distinguishes wetlands according to their dominant hydrological setting. Riverine wetlands are directly associated with river channels and receive water from surface-flow connectivity, whereas palustrine wetlands correspond to non-tidal inland wetlands such as marshes, swamps, bogs and fens.

We agree that not all palustrine wetlands receive significant sediment inputs. In particular, systems such as bogs and many fens are primarily sustained by precipitation or groundwater and are therefore less connected to fluvial sediment transport. For this reason, LOAC-OCB only includes the GLWD classes corresponding to regularly or seasonally flooded wetlands that are connected to the aquatic continuum and therefore potentially involved in sediment and terrestrial POC retention.

To avoid confusion, we have clarified this definition in the revised manuscript:

“Riverine wetlands receive water primarily from river channels and floodplain inundation, whereas palustrine wetlands are non-tidal inland wetlands whose water sources may include precipitation, groundwater, or surface-water inputs. We specifically selected regularly or seasonally flooded systems to increase the likelihood of representing wetlands that are hydrologically connected to the aquatic continuum at the annual temporal scale considered by LOAC-OCB and therefore participate in sediment and terrestrial POC retention processes.”

L120: “biogeochemical and physical”

We thank the referee for pointing this out. We unintentionally omitted the physical component from the description and have corrected the text accordingly in the revised manuscript.

L132-134: In coastal ecosystems, such as saltmarshes, seagrasses and mangroves, the burial may be a bit different. A lot of carbon buried here is produced in situ, and a lot of the sediments come in from the sea, for which coastal currents and tides are controlling factors.

We agree with the referee that burial in coastal ecosystems differs from that in many inland systems. As discussed in the previous comment regarding inputs derived from coastal currents and tides, sediment accumulation in coastal ecosystems is influenced not only by riverine inputs but also by marine sources associated with tidal exchange, coastal currents, wave-driven resuspension, and sediment redistribution. In addition, a substantial fraction of the OC buried in coastal ecosystems can be produced in situ.

Current evidence indicates that the relative contribution of autochthonous and allochthonous OC varies widely among ecosystem types and locations. For example, seagrass-derived OC accounts for a median of approximately 51% of sediment OC, while the remainder originates from external sources (Kennedy et al., 2010, 2022). Similarly, mangrove ecosystems show strongly variable allochthonous contributions ranging from approximately 12% to 70% (Sasmito et al., 2019; Kusumaningtyas et al., 2019; Xiong et al., 2018).

We have therefore added some of this discussion to the Introduction section:

"This terrestrial input is especially dominant in systems such as small lakes with short water residence times, lakes with large watershed areas, or catchments subject to intense erosion (Mulholland and Elwood, 1982). ***Furthermore, terrestrial OC can constitute a substantial fraction of the OC ultimately buried in depositional environments. For example, allochthonous inputs have been shown to dominate soil OC accumulation in some floodplains (González et al., 2014), while other studies indicate that allochthonous OC commonly contributes a large fraction of the sediment OC buried in blue-carbon ecosystems (Kennedy et al., 2022; Sasmito et al., 2020).*** *Compared to autochthonous OC produced within aquatic systems, terrestrial OC tends to be more persistent and less available to microbial degradation (Guillemette et al., 2013; Kothawala et al., 2021), which increases its likelihood of long-term burial (Sobek et al., 2009)."*

As discussed above, LOAC-OCB was specifically designed to represent the transport and fate of terrestrially derived POC along the LOAC rather than total OC burial from all sources.

Kennedy, H., Beggins, J., Duarte, C. M., Fourqurean, J. W., Holmer, M., Marbà, N., & Middelburg, J. J. (2010). Seagrass sediments as a global carbon sink: Isotopic constraints. Global biogeochemical cycles, 24(4).

Kennedy, H., Pagès, J. F., Lagomasino, D., Arias-Ortiz, A., Colarusso, P., Fourqurean, J. W., ... & Duarte, C. M. (2022). Species traits and geomorphic setting as drivers of global soil carbon stocks in seagrass meadows. Global Biogeochemical Cycles, 36(10), e2022GB007481.

Sasmito, S. D., Kuzyakov, Y., Lubis, A. A., Murdiyarso, D., Hutley, L. B., Bachri, S., ... & Borchard, N. (2020). Organic carbon burial and sources in soils of coastal mudflat and mangrove ecosystems. Catena, 187, 104414.

Kusumaningtyas, M. A., Hutahaean, A. A., Fischer, H. W., Pérez-Mayo, M., Ransby, D., & Jennerjahn, T. C. (2019). Variability in the organic carbon stocks, sources, and accumulation rates of Indonesian mangrove ecosystems. Estuarine, Coastal and Shelf Science, 218, 310-323.

Xiong, Y., Liao, B., & Wang, F. (2018). Mangrove vegetation enhances soil carbon storage primarily through in situ inputs rather than increasing allochthonous sediments. Marine Pollution Bulletin, 131, 378-385.

González, E., Cabezas, Á., Corenblit, D., & Steiger, J. (2014). Autochthonous versus allochthonous organic matter in recent soil C accumulation along a floodplain biogeomorphic gradient: an exploratory study. Journal of Environmental Geography, 7(1-2), 29-38.

L170: Mineralization does not release OC, it turns it into CO_2.

We agree with the referee that this sentence is incorrectly phrased. In the revised manuscript, it reads:

"The pool of deposited sediments, defined as the accumulation of particles due to sedimentation, is assumed to have the same OC content as the sediments entering the node. This pool can either be permanently buried or undergo mineralization, releasing CO_2 and CH_4 into the water column."

Eq. 3 doesn't make sense. You don't conserve mass here if OC_input is supposed to be the sum of OC_min and OC_depo.

We apologize for the confusion. We would like to clarify that Eq. 3 only represents the fraction of OC mineralized in the water column and therefore does not, by itself, describe the complete OC mass balance of the ecosystem.

The total OC input is partitioned among several fates: (i) mineralization in the water column (Eq. 3), (ii) sediment deposition, (iii) burial within the sediments, and (iv) downstream export. In addition, the deposited OC is further partitioned into buried OC and OC mineralized within the sediments. Consequently, OC_{input} is not simply equal to $OC_{min}+OC_{depo}$, and mass is conserved only when all fluxes represented in the model are considered together.

We always preserve mass balance at each node. To avoid this misunderstanding, we have revised the text surrounding Eq. 3 and make the complete OC mass balance more explicit in the revised manuscript.

L204: As far as I know, the empirical models by Leopold and Maddock are based on bank-full discharge, which is often substantially higher than mean discharge.

We thank the reviewer for this observation. We acknowledge that hydraulic geometry relationships are often associated with bankfull or channel-forming discharge conditions, which may exceed mean discharge. However, the objective of Eq. 5 in our framework is not to reproduce local channel geometry, but rather to provide a globally consistent estimate of water depth required for the simulation of sediment transport and organic carbon burial. At the global scale, spatially consistent estimates of bankfull discharge are generally unavailable, whereas mean discharge is available worldwide and is consistent with the long-term, steady-state nature of the model.

We note that the representation of higher-flow conditions is partially incorporated through the floodplain component of the model, where floodplain depth is estimated as the difference between depths calculated under maximum and mean discharge conditions (see response to comment L86). As discussed there, we recognize that the current steady-state representation of hydrology does not explicitly resolve temporal hydrological variability or event-driven sediment transport, which remains a limitation of the framework.

Furthermore, the uncertainty associated with the hydraulic geometry relationship appears to have a limited influence on model outcomes. In the global sensitivity analysis, the exponent

(0.3) and coefficient (0.27) of Eq. 5 ranked 13th and 21st, respectively, among all evaluated parameters. This indicates that model predictions are relatively insensitive to uncertainties in these parameters compared with other model assumptions. Nevertheless, future developments could improve this aspect of the model by moving beyond the current steady-state framework and incorporating temporally explicit hydrological conditions, including higher-flow events and alternative discharge metrics where suitable global datasets become available.

As shown in our response to comment (L86), we have added a discussion of this limitation and its potential improvements in the Conclusions and Future Developments section of the revised manuscript.

L207: Please use Q for discharge, q is usually used for runoff.

We thank the reviewer for the suggestion. To follow common hydrological notation and avoid potential confusion with runoff or specific discharge, we have replaced q with Q throughout the manuscript when referring to river discharge.

L209-211: Do you mean bank-full discharge instead of baseflow?

We thank the reviewer for pointing this out. The term "baseflow" was not appropriate here, as floodplain depth is calculated from the difference between maximum and mean discharge conditions rather than between maximum and baseflow conditions. We have revised the text accordingly to avoid confusion. In the revised manuscript, it reads:

"For floodplains, the depth used in model calculations corresponds to the difference in depth between maximum and mean discharge conditions, both estimated using Eq. 5. Given the absence of globally consistent floodplain water-level observations, floodplain inundation depth is approximated as the additional water depth occurring under high-flow conditions relative to average-flow conditions. This simplified representation provides a representative inundation depth, as LOAC-OCB operates at annual timescales and does not explicitly simulate transient flood dynamics."

L221-223: How is maximum discharge defined? Why not rather use a percentile, which makes more sense because you have flooding more than only once? Or what about average discharge above bankfull discharge. See this paper for estimating bankfull discharge: https://doi.org/10.1016/j.jhydrol.2011.08.004

We thank the referee for this comment. As stated in Section 2.5.2, maximum discharge is estimated from the 90th percentile of monthly runoff derived from the ISIMIP3a WaterGAP simulations (Gosling et al., 2025). The percentile calculation was performed using the Climate Data Operator (CDO) software. Therefore, the term "maximum discharge" in the model does not refer to the absolute maximum observed flow, but rather to a high-flow condition.

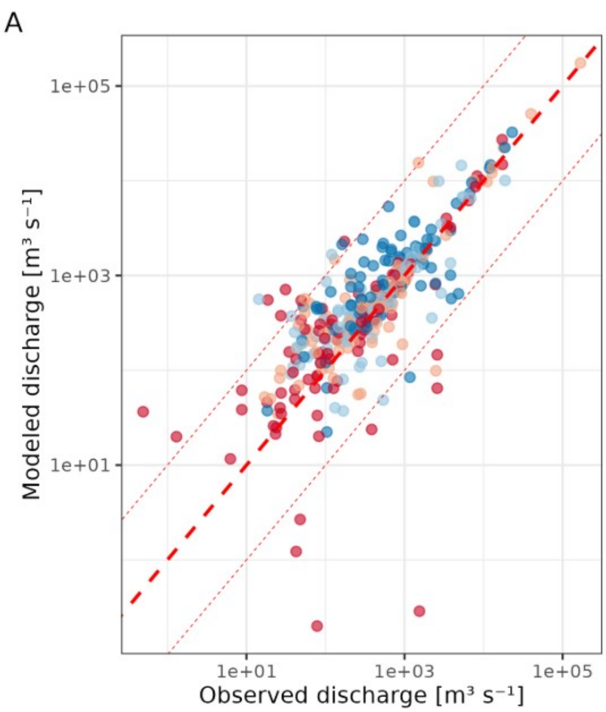
We agree that this was not sufficiently clear in the original manuscript and that part of the confusion was caused by outdated references to Fekete et al. (2002), which were mistakenly retained from an earlier stage of model development. We have corrected this throughout the manuscript.

We chose the 90th percentile because the model operates at the global scale and requires a globally consistent metric to represent high-flow conditions. While bankfull discharge may be physically meaningful for representing floodplain activation, globally consistent bankfull discharge estimates are not readily available. The 90th percentile provides a pragmatic approximation of high-flow conditions while avoiding the disproportionate influence of extreme events associated with absolute maxima.

Accordingly, the text in current L221–223 was revised to:

"In floodplains, RT is calculated using maximum discharge ($Q = Q_{max}$) under the assumption that sediment exchange between rivers and floodplains is generally enhanced during high-flow conditions, when hydraulic connectivity between the channel and the adjacent floodplain increases. Q_{max} is represented by the 90th percentile of monthly runoff derived from the WaterGAP simulations (Gosling et al., 2025) using the Climate Data Operator (CDO) software."

The resulting discharge estimates were evaluated against an independent global dataset, with 94% of modeled discharge values falling within one order of magnitude of observations (Fig. 5A). This provides confidence that the model adequately reproduces the large-scale hydrological patterns relevant for the objectives of this study.



Furthermore, the new sensitivity analysis indicates that uncertainties associated with discharge-derived variables have a relatively limited influence on model outputs. The coefficients used to estimate water depth (parameters d and e) ranked 13th and 21st, respectively, while the hydraulic-radius parameters (f and i) ranked 26th and 28th among the 32 evaluated parameters. This suggests that model predictions are substantially more sensitive to parameters controlling sediment retention, burial efficiency, and mineralization than to the specific formulation used to derive these hydrological variables.

For these reasons, we believe that the current implementation provides a reasonable and robust representation of high-flow conditions for a global-scale application.

L228-229: Do you assume that the eroded and mobilized material is fully disaggregated? Fine textures like clay and fine silt will rather remained bound in aggregates.

We thank the reviewer for this observation. We acknowledge that eroded material is not necessarily fully disaggregated during mobilization and transport, and that fine particles may remain incorporated within aggregates. As a result, the effective transport and settling behavior of sediments may differ from that expected from the individual particle-size fractions represented in the model. However, explicitly representing aggregation and disaggregation processes would require consideration of additional physical, chemical, and biological controls that are currently not available at the global scale.

Importantly, LOAC-OCB already provides a more detailed representation of sediment transport and retention than is commonly adopted in global OC burial models. Rather than treating sediments as a single homogeneous pool, the model explicitly distinguishes clay, silt, and sand fractions, assigns particle-specific settling velocities, and applies ecosystem-specific trapping efficiency formulations. Lakes and reservoirs are represented using particle-size-dependent empirical retention relationships, while coastal systems account for differences in settling velocity among sediment fractions.

While this approach does not explicitly account for aggregation processes, it captures first-order differences in sediment transport and retention that are generally neglected in existing global-scale frameworks. We have added a statement in Section 2.3.2 of the manuscript acknowledging that sediment aggregation and disaggregation are not explicitly represented and may contribute to uncertainty in sediment retention estimates:

"The pool of deposited sediments, defined as the accumulation of particles due to sedimentation, is assumed to have the same OC content as the sediments entering the node. ***The model assumes that sediment particles are transported and deposited according to their assigned clay, silt, and sand fractions. Sediment aggregation and disaggregation processes are not explicitly represented and may therefore contribute to uncertainty in sediment retention estimates.*** *This pool can either be permanently buried or undergo mineralization, releasing OC back into the water column."*

L237: You can have notable sediment and POC transport in rivers without overflowing the river banks. Some river systems may have a flood recurrence of > 1 year, so that the floodplain is not inundated every year.

We agree with the reviewer that substantial sediment and POC transport can occur within river channels without overbank flooding, and that floodplain inundation frequencies vary widely among river systems. Our intention was not to imply that sediment transport is restricted to flood events, but rather that floodplain deposition is generally enhanced during high-flow conditions when hydraulic connectivity between rivers and floodplains increases.

Given the global scale of the model, floodplain processes are represented through a simplified approach in which sediment retention is associated with high-flow conditions. This does not imply annual inundation of all floodplains, but rather provides a consistent global approximation of the conditions under which sediment exchange between rivers and floodplains is most likely to occur.

We think this clarification is best addressed in the preceding text (L221–223). Therefore, we have revised those lines to avoid implying that floodplain sedimentation occurs exclusively during peak flows or that all floodplains are inundated every year. The revised paragraph now reads:

"In floodplains, RT is calculated using maximum discharge ($Q = Q_{max}$) under the assumption that sediment exchange between rivers and floodplains is generally enhanced during high-flow conditions, when hydraulic connectivity between the channel and the adjacent floodplain increases. Q_{max} is represented by the 90th percentile of monthly runoff (Section 2.5 for the derivation and source of Q_{max})."

L238-240: Depending on the water levels, only a fraction of the floodplain may be flooded.

We agree with the reviewer that only a fraction of the mapped floodplain area may be inundated at a given time and that inundation extent varies with hydrological conditions. However, LOAC-OCB does not explicitly simulate floodplain inundation dynamics or the fraction of floodplain area flooded during individual events. Instead, floodplains are represented as aggregated ecosystem units derived from the GLWD dataset, , with floodplain surface area treated as a static ecosystem property. Mineralization is estimated using a representative residence time and sediment retention through a fixed trapping efficiency derived from Noe and Hupp (2009), rather than through the explicit simulation of deposition across dynamically varying inundated areas. This approach provides a parsimonious representation of floodplain mineralization and sediment retention suitable for global-scale application, while acknowledging that spatial and temporal variations in inundation extent are not explicitly resolved.

To clarify these points in the revised manuscript, we have added the following sentences:

In Section 2.4.1, current L201: *"Floodplain and coastal areas are treated as static ecosystem properties and are not dynamically adjusted according to temporal changes in inundation extent."*

In Section 2.5.2, current L334: *"Floodplain surface area is represented as a static ecosystem property aggregated at the floodplain-unit scale. Consequently, the model does not explicitly simulate temporal variations in inundation extent or the fraction of floodplain area flooded under different hydrological conditions."*

Figure 3: Why exactly did you fit a sigmoidal relationship and not simply a linear relationship between OCBE and ln(LSR)? Also, your fit is strongly affect by the single value by Sobek et al. (2012). How would the fit change if you removed that one value? This makes your fit very uncertain. The values after Mendonça et al. seem to follow a different trend. Such uncertainties and potential biases need to be discussed.

We thank the referee for this important observation. The rationale for adopting a sigmoidal relationship rather than a linear relationship between OCBE and ln(LSR) is primarily conceptual. OCBE is a proportion bounded between 0 and 100%, whereas a linear model does not impose such constraints and could yield unrealistic values outside the physically meaningful range. In contrast, a sigmoidal function naturally represents the expectation that burial efficiency should increase with sedimentation rate while asymptotically approaching an upper limit. Since OCBE represents the fraction of deposited OC that is ultimately buried, values above 100% are physically impossible and values approaching an upper limit are expected at high sedimentation rates.

Furthermore, the objective of this relationship is not merely statistical fitting. The OCBE–LSR formulation provides a mechanistic link between sediment accumulation and carbon preservation, allowing burial efficiency to respond to differences in sedimentation while remaining physically consistent across the wide range of conditions represented globally. Although the available OCBE dataset remains limited, the resulting relationship produces modeled burial rates and global fluxes that are consistent with observational ranges and independent global estimates, providing confidence that it captures the dominant controls on terrestrial POC burial at the global scale. The adequacy of the relationship is therefore evaluated not only by the quality of the fit itself, but also by the ability of the complete LOAC-OCB framework to reproduce plausible global fluxes.

We nevertheless agree that the fit may be influenced by a limited number of observations, including the high-OCBE point reported by Sobek et al. (2012), and that potential dataset-dependent biases deserve further examination. Following the referee's suggestion, we explored the sensitivity of the fitted parameters by (i) removing the Sobek et al. (2012) point, and (ii) fitting the relationship separately to the Mendonça et al. (2016) reservoir data. For (i), we obtained $b = 0.7094$ and $c = -0.7814$, which are virtually identical to the original values ($b = 0.7068$ and $c = -0.780$), indicating that the fit is not strongly driven by the Sobek et al. (2012) observation. For (ii), we obtained $b = 0.969$ and $c = -0.861$. The steeper relationship is expected because the Mendonça dataset is composed exclusively of reservoirs, which tend to exhibit higher burial efficiencies than the broader set of freshwater ecosystems considered in our calibration dataset. Importantly, the fitted value of c falls well within the 95% bootstrap uncertainty range, while the fitted value of b lies very close to its upper limit. This suggests that the reservoir-only relationship represents a plausible end-member within the uncertainty already captured by the freshwater model, which was intentionally designed to represent multiple freshwater ecosystem types, rather than evidence for a fundamentally different calibration.

We agree that the available dataset is limited and that additional observations would improve the characterization of the relationship between OCBE and LSR, particularly for specific ecosystem types. The apparent differences between reservoir and lake observations highlight the need for a larger OCBE database and potentially ecosystem-specific relationships in future model versions. One of the motivations of this work is to encourage the routine reporting of OCBE, as it provides a useful and transferable metric for scaling burial processes across aquatic ecosystems. In particular, increasing OCBE observations in underrepresented environments such as floodplains would enable the development of ecosystem-specific parameterizations and reduce uncertainty in future global-scale modeling efforts.

To further address this uncertainty, we performed an additional analysis based on a non-parametric bootstrap of the fitted sigmoidal relationship (1,000 iterations). Each bootstrap realization generated a new estimate of the sigmoid parameters b (slope) and c (inflection point), allowing us to quantify parameter uncertainty and derive a 95% uncertainty envelope around the fitted relationship. These bootstrap-derived parameter distributions were subsequently propagated through the broader uncertainty framework used to estimate uncertainty in OC burial, ensuring that uncertainty associated with the empirical OCBE–LSR relationship is explicitly reflected in later model simulations.

Importantly, the bootstrap uncertainty envelope shown in the revised Fig. 3 encompasses the variability associated with the alternative fits explored above, providing additional confidence that the selected freshwater relationship is robust despite the limited size of the observational dataset.

To make this clear in the revised manuscript, we have added the following paragraph to Section 2.4.5 (L265), and updated Fig. 3 and its caption accordingly:

"To quantify parameter uncertainty in the freshwater relationship, we performed a non-parametric bootstrap analysis (1,000 iterations) of the sigmoidal fit. The resulting distributions of the model parameters b and c were used to define a 95% bootstrap uncertainty envelope around the fitted relationship (Fig. 3). The bootstrap-derived parameter ranges were subsequently propagated through the uncertainty framework used to estimate uncertainty in OC burial. Because the coastal relationship was derived by adapting the published marine relationship of Katsev and Crowe (2015), rather than fitting an independent marine observational dataset, no bootstrap uncertainty envelope was estimated for the coastal curve."

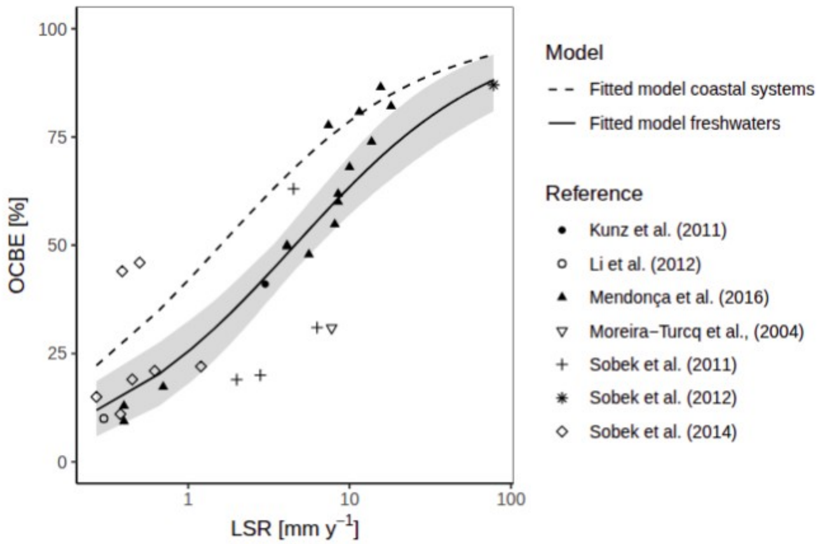


Figure 3. Sigmoidal relationship between organic carbon burial efficiency (OCBE, in %) and linear sedimentation rate (LSR, in mm y^{-1}) derived from 30 observational data points across 13 lakes and reservoirs. Symbols indicate different data sources. The solid curve represents the empirical model fitted to freshwater observational data by Henry et al. (2024) (Eq. 13) and is applied to lakes, reservoirs and floodplains. The dashed curve represents an equivalent sigmoidal relationship derived to reproduce the marine OCBE-sedimentation relationship reported by Katsev and Crowe (2015) and is used for coastal systems; the underlying marine observations are not shown. The shaded area indicates the 95% bootstrap uncertainty envelopes obtained from 1000 realizations of the fitted freshwater sigmoidal model, reflecting uncertainty in the parameters b and c. The same bootstrap-derived parameter uncertainty was subsequently propagated through the OC burial model simulations.

L277-278: you mean "carbon mass balance"?

We thank the referee for pointing this out. The source of the confusion was not the term "sediment mass balance", but a typographical error in Eq. 14, where we mistakenly wrote OCdepo instead of SEDdepo. We apologize for this oversight. The corrected equation is:

$SED_{bur} = SED_{depo} - OC_{min\text{-}sed}$

The correct version of the equation was already reported in Table B4, and we have revised the manuscript accordingly to ensure consistency throughout the text.

Eq. 14: the name SED_bur is confusing. It's OC that is buried, not sediments.

We thank the referee for this observation. We agree that the notation can be confusing at first glance. However, SEDbur does not refer to buried OC, but to the mass of sediment that remains after accounting for sediment mineralization and is ultimately accumulated in the sediment column. This variable is required to estimate linear sedimentation rates (LSR), which are used to calculate OC burial efficiency (OCBE). OC burial itself is represented separately by OCbur. To avoid confusion, we have clarified the definition of SEDbur in the revised manuscript and ensure that the distinction between sediment burial and OC burial is explicit.

In Section 2.4.5, current L267: *"The first iteration starts with the assumption that the sediment burial rate (SED_{bur}, in kg m^{-2} y^{-1}), representing the mass of sediment ultimately buried within the sediment column after accounting for OC mineralization, and its OC content ($\%OC_{bur}$) are equal to SED_{depo} and $\%OC_{depo}$, respectively."*

In Section 2.4.5, current L280: *"Note that SED_{bur} represents sediment burial and not OC burial, which is represented separately by OC_{bur}."*

L292: Give a reference for that dataset.

We agree with the referee that data sources should be referenced not only in Section 2.5, where the inputs are described in detail, but also when they are first introduced in the manuscript. We have revised the text accordingly for all major input datasets.

For example, the sentence referred to by the referee was revised to:

"For river and coastal burial nodes, the model uses yearly mean river temperatures, while for lakes, reservoirs, and floodplains, yearly mean bottom lake temperatures are applied. These data are derived from ISIMIP3a WaterGAP and GOTM simulations (Gosling et al., 2019; see details in Section 2.5.2)."

We applied the same approach throughout the manuscript to improve traceability of the input data sources.

L338-339: Why don't you calculate that from the WaterGAP data?

We thank the referee for noting this. As clarified in our response to comment L221–223, both runoff and Qmax are derived from the ISIMIP3a WaterGAP simulations (Gosling et al., 2025).

L346: You should have given that reference way earlier.

We agree with the referee. As discussed in our response to comment L292, we now provide references to the input datasets when they are first mentioned in the manuscript, including the temperature datasets referred to here.

L353-354: The estimate of sediment mobilization into the LOAC is the most critical component of the overall estimation framework and should therefore be introduced, named, and described much earlier in the manuscript. However, this dataset does not actually quantify sediment delivery to the LOAC; rather, it represents gross hillslope erosion. A large fraction of this eroded material is likely to be intercepted and stored at the footslope or elsewhere within the catchment before ever reaching the LOAC. Using this estimate directly as a proxy for sediment inputs to the LOAC will therefore almost inevitably lead to an overestimation of sediment mobilization. If the aim is to estimate sediment delivery from a watershed to the aquatic network, MUSLE-based estimates would be more appropriate.

We thank the referee for this comment. As discussed in our response to the general comment regarding gross hillslope erosion and sediment delivery, we acknowledge that intermediate sediment storage processes are not explicitly represented in LOAC-OCB.

However, the GloSEM product provides a globally consistent estimate of soil loss suitable for large-scale applications and is one of the few datasets available for global assessments of sediment mobilization.

We agree that MUSLE-based approaches can be advantageous for estimating event-scale sediment delivery at watershed scales. However, LOAC-OCB is a steady-state global model designed to represent long-term average fluxes and therefore requires globally available datasets that can be applied consistently worldwide.

Importantly, the resulting sediment transport is independently evaluated against observations. Comparisons with the dataset of Dethier et al. (2022) show good agreement, with 94% of discharge values and 64–72% of sediment-related variables falling within one order of magnitude of observations. In addition, the terrestrial POC input (0.48 Pg C y^{-1}) and export estimates are consistent with recent global assessments, including Tian et al. (2026), providing additional confidence that sediment and OC mobilization are not being systematically overestimated (see Table 2 above).

L354-356: HWSD also has information on soil texture and soilgrids (cited here) also has estimates on topsoil OC content. I don't see why you would use different data sources for these two important soil properties. That introduces unnecessary inconsistencies.

We thank the referee for this observation. We agree that using a single soil database for multiple variables could improve consistency among model inputs. However, our choice was guided by the characteristics of the individual datasets rather than by consistency alone.

We used the HWSD product for soil OC content because it provides a globally consistent estimate of topsoil carbon content and has been widely used in previous global carbon studies. In contrast, particle-size fractions were derived from SoilGrids 2.0 (Poggio et al., 2021), which is a substantially more recent product, provides much finer spatial resolution, and is based on modern digital soil mapping techniques supported by a greatly expanded global database of soil observations. For the characterization of clay, silt, and sand fractions, SoilGrids therefore represents one of the most suitable datasets currently available at the global scale.

We acknowledge that combining datasets may introduce some degree of inconsistency between soil properties. However, we considered that the benefits of using the improved representation of soil texture provided by SoilGrids outweighed this drawback. Furthermore, the sensitivity analysis indicates that model outputs are substantially more sensitive to parameters controlling sediment retention, burial efficiency, and mineralization than to the exact parameterization of soil physical properties.

Nevertheless, we agree that the rationale behind this choice should be made more explicit therefore we have clarified this in Section 2.5.3 of the revised manuscript:

“The relative proportions of clay, silt and sand within the sediment loads are derived from Poggio et al. (2021), which provides a high-resolution representation of global soil texture based on modern digital soil mapping techniques.”

Table 1: What do these WaterGAP simulations take into account? Are those naturalized flows or do they account for instance for irrigation? That would be important to clarify. Is “Runoff max” also derived from WaterGAP?

We thank the referee for this important question. As clarified in our response to comment L221–223, both Runoff and Runoff max are derived from the ISIMIP3a WaterGAP simulations (Gosling et al., 2025). Specifically, Runoff max corresponds to the 90th percentile of monthly runoff calculated from the WaterGAP time series using the Climate Data Operator (CDO) software. These simulations account for major anthropogenic influences on the hydrological cycle, including water withdrawals and water management processes represented within the WaterGAP framework.

We have revised the manuscript to clarify the characteristics of the WaterGAP simulations used in this study. In the revised version, Section 2.5.2 now reads:

“Runoff, the climatic driver for discharge in the model, is obtained as monthly mean (kg m^{-2} s^{-1}) from the ISIMIP3a data repository, using the WaterGAP simulations for the period 1901–2015 (Gosling et al., 2025). The runoff variable represents the total runoff contributing to river discharge, including both surface and subsurface flow components, and incorporates the effects of major water-use sectors represented in WaterGAP, including domestic, manufacturing, power-generation, livestock, and irrigation demands. [...] Maximum discharge is estimated from the 90th percentile of monthly runoff derived from the same WaterGAP time series (Gosling et al., 2025), using the Climate Data Operator (CDO) software.”

Additional information on the WaterGAP simulations is available at:

https://www.isimip.org/impactmodels/details/313/

L369-370: You should use observed discharge from the GRDC (https://grdc.bafg.de/).

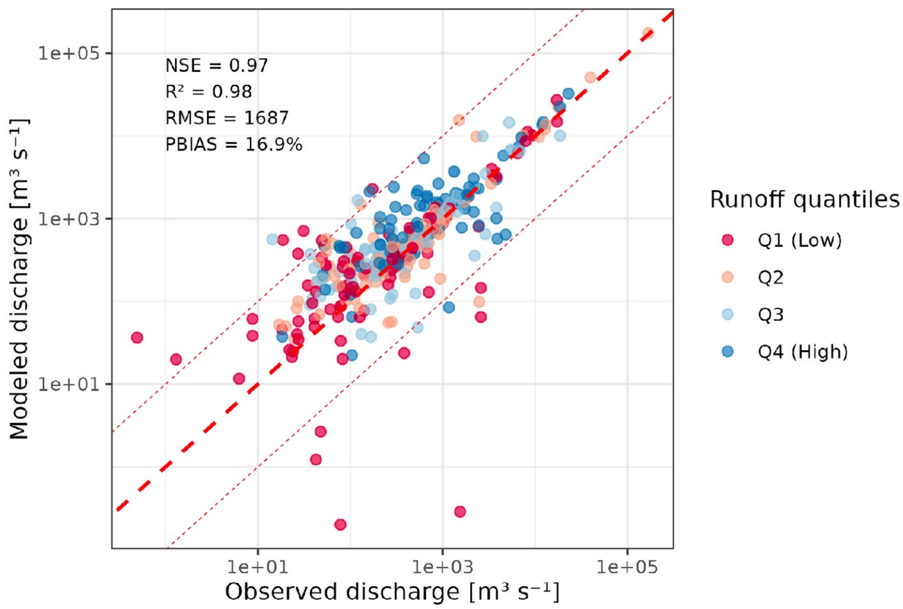
We thank the referee for this suggestion. As clarified in our responses to comments L221–223, L338-339 and Table 1, the references to Fekete et al. (2002) were mistakenly retained from an earlier stage of model development and do not correspond to the hydrological inputs used by LOAC-OCB. We believe that correcting this inconsistency should resolve this concern.

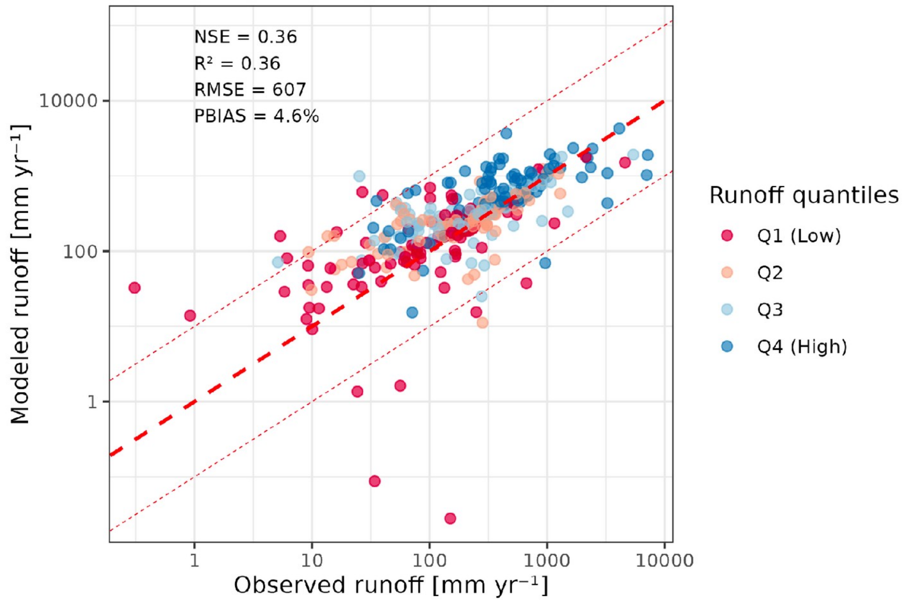
Figure 5: You should report here some useful metrics, maybe a combination of NSE, R2, RMSE and MBE (mean bias error). In panels a) and b), you should normalize fluxes by watershed size (like mm/yr for discharge and t/km2/yr for sediments). Otherwise I have the feeling that these correlations are only the result of differences in watershed size, which have nothing to do with the goodness of the model.

We thank the referee for this suggestion. We agree that including quantitative performance metrics improves the assessment of model performance. We have therefore added NSE, R^2, RMSE, and PBIAS (a normalized measure of model bias) to the revised figure.

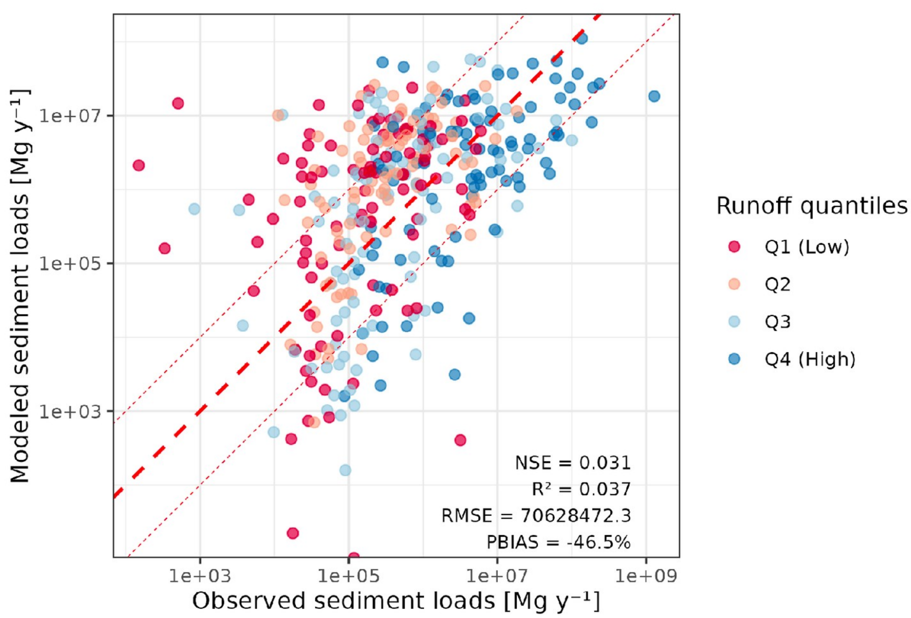
Following the referee's suggestion, we also evaluated model performance after normalizing discharge by watershed area and expressing it as runoff (mm yr^{-1}). While the strong agreement observed for absolute discharge decreased after normalization (R^2 from 0.98 to 0.35; NSE from 0.97 to 0.36), the normalized comparison reduced the overall bias (PBIAS from 16.9% to 4.6%), indicating that the model reproduces mean runoff production reasonably well but is less successful at capturing basin-to-basin variability in runoff yield.

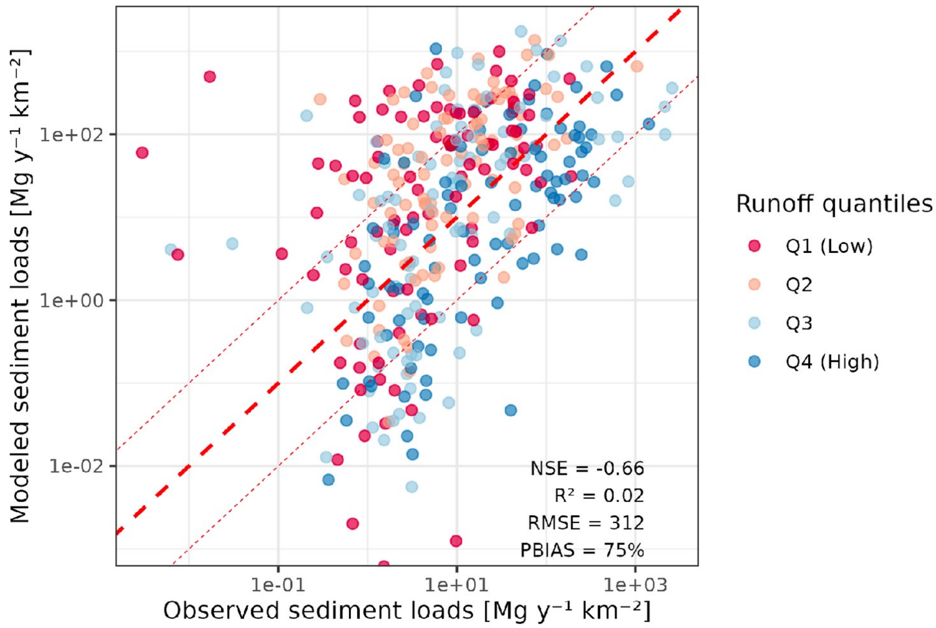
Nevertheless, the primary objective of this validation is to evaluate the model's ability to reproduce river discharge, which is the variable directly represented in the hydrological network. We therefore consider the comparison against observed discharge to be the most relevant benchmark, while the normalized analysis provides complementary information on runoff production independent of watershed size. Across 371 stations, 94% of modeled discharge values fall within one order of magnitude of the observations.



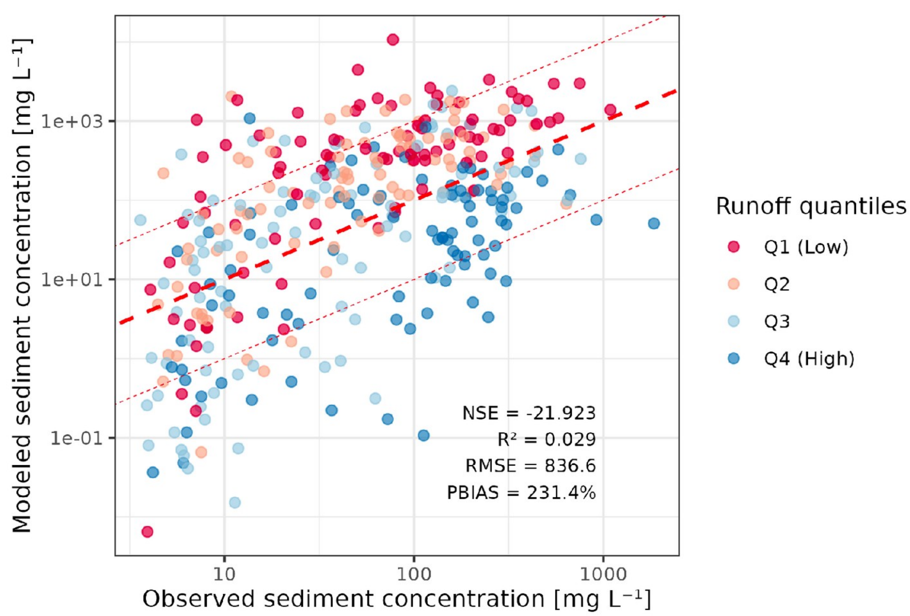


A similar evaluation was performed for sediment loads normalized by watershed area and expressed as specific sediment yields (Mg km^{-2} yr^{-1}). Model performance metrics decreased relative to the comparison based on total sediment loads (R^2 from 0.04 to 0.02; NSE from 0.03 to -0.66), indicating that the model captures total sediment transfers more successfully than spatial variability in sediment yield. Because LOAC-OCB simulates sediment transport through the river network, we consider total sediment loads to be the most relevant validation benchmark. Across 359 stations, 60% of modeled sediment loads fall within one order of magnitude of the observations.





To further address the influence of watershed size, we note that the comparison with suspended sediment concentrations already evaluates model performance independently of discharge magnitude and basin area effects. A comparable evaluation was therefore performed for suspended sediment concentrations, and the revised figure now includes NSE, R^2, RMSE, and PBIAS. Model performance metrics were lower ($R^2 = 0.03$; NSE = -21.9; PBIAS = 231.4%), indicating substantial deviations at individual sites. Nevertheless, 71% of modeled concentrations fall within one order of magnitude of observations, supporting the ability of the model to reproduce realistic sediment dynamics at the scale required for global applications.



L386-380: These bootstrapped uncertainties around these median values have no meaning. For your simulation, they are extremely low due to the huge number of simulated values. You should rather try to quantify the actual uncertainty of your results.

We thank the referee for this important observation. We agree that the bootstrap uncertainty originally reported around median values primarily reflected the size of the simulated population rather than uncertainty associated with the model itself.

In response to this and related comments, we conducted a global sensitivity analysis (Morris method) and a parameter uncertainty analysis based on 1,000 realizations of the most influential parameters. The uncertainty estimates reported in the revised manuscript therefore now represent uncertainty propagated through the model framework rather than uncertainty in sample statistics.

Accordingly, Section 3.2, current L386–395 have been revised as follows:

"Modeled LSR varies within one order of magnitude across ecosystem types (Fig. 6). The highest median rates were found in reservoirs (9.16 ± 0.94 mm y^{-1}) and coastal systems (5.19 ± 0.69 mm y^{-1}), while the lowest rates occurred in lakes (0.30 ± 0.04 mm y^{-1}) and floodplains (0.49 ± 0.07 mm y^{-1}). Observed values follow a similar pattern: highest medians in reservoirs (10.80 ± 2.95 mm y^{-1}) and coastal systems (4.55 ± 0.55 mm y^{-1}), and lowest in lakes (2.00 ± 0.60 mm y^{-1}) and floodplains (3.75 ± 0.42 mm y^{-1}).

Modeled OC_{bur} rates follow the same trend. Reservoirs showed the highest median OC_{bur} rate (90.99 ± 7.23 g C m^{-2} y^{-1}), followed by coastal systems (51.59 ± 5.48 g C m^{-2} y^{-1}), floodplains (1.54 ± 0.51 g C m^{-2} y^{-1}) and lakes (1.10 ± 0.42 g C m^{-2} y^{-1}) (filled boxes in Fig. 6). Observed values are about one order of magnitude higher, with highest medians in coastal systems (134.0 ± 10.3 g C m^{-2} y^{-1}), followed by floodplains (104.0 ± 12.7 g C m^{-2} y^{-1}), reservoirs (101.0 ± 28.3 g C m^{-2} y^{-1}), and lakes (25.0 ± 1.4 g C m^{-2} y^{-1})."

L396-404, Figure 6: The large differences between modelled and observed burial rates may partly reflect biases in the observational dataset, which appears to be skewed towards systems with higher burial rates. Based on the spatial distribution of the observations, you should narrow the regions from which simulated values are extracted and perhaps apply a weighting according to the number of observations in each region, in order to improve the comparability between observations and simulations.

We thank the referee for this suggestion. We agree that the observational dataset is not spatially uniform and that some regions are much better represented than others. However, the objective of Fig. 6 is not to compare modeled and observed systems on a one-to-one basis, but rather to evaluate whether the distributions and ranges of simulated LSR and OC burial rates are consistent with those currently reported in the literature for each ecosystem type and, where discrepancies occur, to identify and discuss the processes, assumptions, scale mismatches, or observational biases that may explain them.

We therefore chose to compare the full distributions of modeled and observed values rather than restricting the analysis to regions with more observations. While such an approach could improve geographical correspondence, it would also reduce the ability of the comparison to evaluate the global behavior of the model and would introduce additional sampling biases associated with the uneven spatial distribution of observations.

In fact, one of the main findings from Fig. 6 is that differences between modeled and observed values are not uniform across ecosystem types. For example, reservoirs and coastal ecosystems show substantial overlap between modeled and observed distributions, whereas larger discrepancies are observed in floodplains and, to a lesser extent, lakes. These differences constitute valuable diagnostic information and motivated the discussion of potential causes, including scale mismatches, exclusion of small lakes, differences in carbon pools considered, and biases in the observational datasets toward systems with high sedimentation and burial rates.

We nevertheless agree that the limited size and uneven spatial distribution of the observational database represent important limitations when evaluating a global model. Furthermore, Fig. 6 is only one component of the overall model evaluation framework, which now includes independent validation of discharge, sediment loads, sediment concentrations, a global sensitivity analysis, and a parameter uncertainty analysis.

L405-412: How large may be the contribution of that autochthonous OC in the total OC burial? For lakes and reservoirs, it may be small, but what about floodplains and coastal wetlands?

We thank the referee for this important observation. We agree that the contribution of autochthonous OC to total OC burial likely differs among ecosystem types and may be substantial in some coastal and floodplain environments.

As discussed in our response to comment L132-134, for coastal wetlands, current evidence suggests that both allochthonous and autochthonous sources contribute substantially to buried OC. Global syntheses indicate that seagrass-derived OC accounts for a median of approximately 51% of sediment OC, while the remainder originates from external sources (Kennedy et al., 2010, 2022). Similarly, studies in mangrove ecosystems report allochthonous contributions ranging from approximately 12% to 70%, depending on local environmental conditions (Sasmito et al., 2019; Kusumaningtyas et al., 2019; Xiong et al., 2018).

For floodplains, the available evidence indicates strong variability associated with hydrological connectivity. Hein et al. (2003) found that particulate organic matter in a Danube floodplain was often dominated by autochthonous production during periods of low connectivity, whereas river-derived material dominated during flood events. In contrast, González et al. (2014) found that more than 80% of accumulated soil organic carbon in a Mediterranean floodplain originated from allochthonous inputs, even in relatively old floodplain forests. Collectively, these studies suggest that the relative contribution of autochthonous and allochthonous OC in floodplains is highly site specific and remains poorly constrained at large spatial scales.

As discussed in our response to comment L132-134, we have incorporated this discussion into the Introduction to better clarify the scope of LOAC-OCB and the role of allochthonous versus autochthonous OC in depositional environments.

Hein, T., Baranyi, C., Herndl, G. J., Wanek, W., & Schiemer, F. (2003). Allochthonous and autochthonous particulate organic matter in floodplains of the River Danube: the importance of hydrological connectivity. Freshwater biology, 48(2), 220-232.

L416: In how far is the Okavango Delta a floodplain? Isn't it an inland delta and endorheic wetland?

We thank the referee for this observation. We agree that the Okavango Delta is more precisely described as an inland delta and endorheic wetland system. However, we used this example following Bernal and Mitsch (2013), who refer to the Okavango as a vast floodplain complex and classify it as a seasonal riverine floodplain (their Table 1). We nevertheless refined the wording to avoid confusion and explicitly distinguish the Okavango Delta from the Rhine and Amazon floodplain systems:

"In contrast, large wetland systems such as the Okavango Delta (endorheic inland delta), and extensive river-floodplain systems such as the Rhine and Amazon, extend across ~15,000 km² (Bernal and Mitsch, 2013), 125,000 km² (Hoffmann et al., 2013), and 6,000,000 km² (Sanders et al., 2017), respectively."

L459-460: How does that really compare to other estimates? The Drake et al. estimate doesn't account for floodplains and coastal systems. There burial in lakes and reservoirs in that budget is only up to 0.6 Pg C/yr. The largest losses in that budget is the emission of CO_2 to atmosphere, and it is not clear how much of that comes from OC that is decomposed in the LOAC. For that you could look at the estimate by Battin et al., 2023. How large is your mineralization flux? And, moreover, how large is the mobilization of terrestrial organic C into the LOAC that you get (and which should be the sum of burial, mineralization and export to the coast)? For this, you should also take into account that the estimates of fluvial exports of C (Drake et al., or Liu et al.) are exports to the coast; the coastal wetlands would come further downstream in the LOAC.

Battin et al., 2023, https://doi.org/10.1038/s41586-022-05500-8

We thank the referee for these observations. The points raised here regarding (i) the comparison with Drake et al. (2018), (ii) the distinction between terrestrial POC, total OC, and total carbon fluxes, (iii) the inclusion of floodplains and coastal ecosystems, (iv) the magnitude of mineralization and terrestrial POC mobilization fluxes, and (v) the distinction between export to the coast and downstream coastal processing have been addressed in detail in our responses to the previous comments concerning Table 2 and the global carbon budget comparison (Section 3.5).

In particular, the revised manuscript, Section 3.5, now reports the corrected global flux estimates, explicitly quantifies uncertainty in burial, mineralization, and export fluxes, and expands the comparison with more recent studies, including Battin et al. (2023), Beusen et al. (2005), and Tian et al. (2026). We also revised Table 2 to clearly indicate the carbon pools, ecosystem coverage, and flux definitions associated with each study, thereby improving the transparency and comparability of the reported estimates.

L463: That is extremely huge considering that terrestrial C inputs are dominated by IC (see Battin et al., 2023).

We thank the referee for this observation. As discussed in our responses regarding the global flux estimates and Table 2, revisiting this section led us to identify an erratum in the reported flux values. The corrected estimate of terrestrial POC input to the LOAC is 0.482 Pg C y^{-1} associated with 34.55 Pg y^{-1} of sediment input, rather than the values originally reported in the manuscript. This affects only the reported values in the manuscript and does not alter the model calculations, underlying processes, or conclusions.

With these corrected values, the apparent inconsistency highlighted by the referee is resolved. We revised the manuscript accordingly and updated the comparison with recent studies, including Battin et al. (2023), as discussed above.

L465-467: Again, this is the flux to the coast, the coastal wetlands come further downstream in the LOAC. Also, Liu et al. give estimates of dissolved and particulate OC exports.

We thank the referee for this observation. We agree that the distinctions among studies could have been presented more clearly to avoid potential misinterpretations, particularly regarding ecosystem coverage, carbon pools represented, and the position of coastal ecosystems within the LOAC.

As discussed in our previous responses, the entire comparison section has been substantially revised. In the revised manuscript, we provide a more explicit description of the scope and definitions used by each study, and Table 2 has been updated to clearly differentiate the carbon pools and fluxes being compared. We believe that this revised presentation better reflects the similarities and differences among studies and facilitates a more robust interpretation of the results.

The entire revised Section 3.5 and Table 2 have been provided above in this document.

L469-472: Regnier et al. include OC exports from coastal wetlands like mangroves and saltmarshes to the sea. I understand that you represent these wetlands rather as sinks than as sources of OC, am I right?

We thank the referee for this observation. If we correctly understand the comment, the referee is asking whether coastal wetlands are represented differently in the two frameworks. In LOAC-OCB, mangroves and saltmarshes are represented as coastal ecosystem components in which terrestrial POC can be transported, mineralized, buried, or exported to the ocean. Therefore, they are not treated exclusively as carbon sinks. However, unlike Regnier et al. (2022), our framework only follows the fate of terrestrial POC, whereas their synthesis represents the broader aquatic carbon cycle and includes additional carbon pools such as DOC and DIC. We therefore believe that differences in the carbon pools considered are the primary reason why the two estimates are not directly comparable. To improve clarity, we substantially revised this comparison in Section 3.5 and Table 2, which now explicitly identifies the carbon pools, carbon sources, and ecosystem types represented by each study.

L480-481: I didn't read that you have a representation of floodplain erosion. Isn't there always a net-deposition on floodplains in your model? And do Li et al. represent burial on floodplains themselves? Or do they just represent burial in lakes and reservoirs? Maybe this comparison doesn't add up?

We thank the referee for this observation. We agree that the original wording was unclear. LOAC-OCB does not explicitly represent floodplain erosion, and Li et al. (2022) do not explicitly account for floodplain or coastal-ecosystem burial. We therefore revised Section 3.5 to avoid this implication and to distinguish more clearly between comparisons of terrestrial POC inputs, land-to-ocean export fluxes, reservoir burial, and total LOAC burial. The revised text now emphasizes that differences among studies often arise from contrasting ecosystem coverage and carbon pools considered, and that direct comparisons should therefore be interpreted with caution.

L483-484: Are you sure that Tranvik et al., 2009 used a mass balance approach to estimate OCB?

We thank the referee for pointing this out. We agree that describing Tranvik et al. (2009) as a mass-balance study was not accurate. Their estimate was derived from a global synthesis and extrapolation of observational data and previously published burial rates rather than from a mass-balance modelling framework. This statement has been removed in the revised manuscript as part of a broader revision of the comparison with previous global estimates.

L485-486: But you do not represent burial on hillslopes, or do you? The burial on hillslopes is like much larger than that on floodplains.

We thank the referee for this observation. LOAC-OCB does not explicitly represent carbon burial on hillslopes. As discussed in our response regarding gross hillslope erosion and sediment mobilization, the model does not resolve hillslope–channel connectivity, intermediate sediment storage, or burial in terrestrial depositional environments. The estimate reported by Aufdenkampe et al. (2011) was only intended to provide broad context because of the lack of global studies specifically addressing OC burial in floodplains. Furthermore, Section 3.5 has been substantially revised to clarify the ecosystem types and carbon pools represented in the different studies used for comparison. We hope these revisions resolve this ambiguity and make the scope of the comparisons considerably clearer. To avoid further misinterpretation, we no longer use this reference in the revised comparison. The revised text reads:

"To our knowledge, floodplains have not been explicitly represented in previous long-term OCB modelling frameworks (Hoffmann et al., 2013), limiting direct comparisons with existing studies. One of the few relevant estimates is that of Bridgham et al. (2014), who revised the global C sequestration potential of wetlands originally reported by Mitsch et al. (2013) and obtained a value of 0.096 Pg C y^{-1}. Notably, this estimate is remarkably close to our floodplain OCB flux (0.093 0.010 ± Pg C y^{-1}). However, their study included a broad

range of wetland types, such as mineral-soil wetlands and boreal peatlands, treated as part of the terrestrial system, making it difficult to evaluate the degree of overlap with the floodplain systems represented in LOAC-OCB.

The absence of comparable global estimates highlights a major knowledge gap in current large-scale carbon assessments. One of the main goals of LOAC-OCB is therefore to provide a simple, process-based framework that explicitly incorporates floodplains into Earth System models and global carbon budgets. While we acknowledge the scarcity of global observations available for model validation, the agreement between our estimates and independent studies, together with the successful validation of the underlying hydrological and sedimentary processes, suggests that the framework provides a promising first-order approximation of floodplain OC burial at the global scale."

L496: That is the upper range of estimates they synthesized, and this is based on an error published by Sawakuchi et al. for the lower Amazon (see my comment above). Also, only a fraction of that CO_2 emissions would be contributed by OC mineralization within the LOAC. See Battin et al., 2023 and my comments above.

We agree with the referee and have addressed this issue in several previous comments. As discussed above, Drake et al. (2018) is no longer used as a primary reference in the revised manuscript due to the limitations identified by the referee. We hope that the substantially revised Section 3.5, including the updated comparison with Battin et al. (2023) and other recent studies, clarifies these distinctions and resolves this concern.

L518: That would require a corresponding estimate for soil erosion.

We thank the referee for this observation. We agree that applications under climate and land-use change scenarios would require corresponding estimates of soil erosion, together with runoff projections, as these are the main drivers used to estimate terrestrial POC mobilization in LOAC-OCB. We have clarified this point in the revised manuscript.

The revised sentence now reads:

"In addition, LOAC-OCB could be extended to long-term simulations or applied to climate and land-use change scenarios, considering that projections of runoff and soil erosion would be required to estimate the corresponding terrestrial POC mobilization."

L520-522: You could also vary number of reservoirs depending on dam construction. More importantly, you could keep track of OC stock changes at erosion and deposition sites.

We thank the referee for these suggestions. We agree that both aspects represent valuable directions for future developments of LOAC-OCB. In addition to accounting for temporal changes in reservoir volume, future model versions could incorporate changes in the number and distribution of reservoirs associated with dam construction and removal. We also agree that explicitly tracking OC stock changes at erosion and deposition sites would provide a more complete representation of terrestrial–aquatic carbon transfers and storage dynamics along the LOAC.

Accordingly, we have expanded this paragraph in the revised manuscript. The revised text now reads:

"In this context, certain state variables could be treated as non-steady. For example, reservoir water volume and the number of reservoirs could vary over time as a consequence of hydrological variability and dam construction, affecting residence times and, consequently, sediment and OC burial. Furthermore, future developments could explicitly track OC stock changes at erosion and deposition sites, enabling a more comprehensive representation of OC redistribution and storage across the LOAC."