- **The model validation for sediment suffers from lack of sediment data. A more thorough evaluation of could help to interpret the modeling results further. For example, analyzing a range of flows sampled for sediment could help to see whether the assumption that average load derived from sampled concentrations is equal to average load per day for a given month or a year (eq. 18-19). Perhaps another estimation method that considers flow changes during the month could have been applied.**

<u>*Answer:*</u>

Thank you for raising this concern about the assumption regarding the observed sediment data. To address this limitation, a sediment rating curve will be fit using the available paired sediment concentration and discharge data across the observation period. By applying this relationship to the continuous daily discharge data, we can estimate sediment loads on a daily scale and aggregate these values to produce more representative monthly sediment loads. This approach accounts for flow variability within each month and addresses the limitations of sparse sediment sampling.

- **The abstract highlights that the method accounts for land use changes and entrapment of sediments in lakes and reservoirs. However, there is very little description of the land use or how the land use changes were included in the model development and how they affected the results. How often did the land use change at the cell level? Can it be used to explain some of the sediment behavior? Did it help to improve the model performance? It seems counterintuitive to talk about land use changes and then only analyze average behavior.**

<u>*Answer:*</u>

Land use changes were incorporated dynamically at an annual time step through the cover management factor (C-factor) in RUSLE, which reflects the vegetation cover's influence on erosion. The land cover data from PCRGLOB-WB provided spatial and temporal variability in land use across the Amazon basin.

In the RDSM model, land use changes were represented at the cell level using fractional distributions of multiple land cover types. These land cover fractions were updated dynamically on a monthly basis based on historical data from 1980 to 2009, with a spatial resolution of 5 arc minutes (~10 km).

This dynamic approach allowed the model to account for changes in key sediment-related factors, such as the cover management factor (C) and interception (Int), both of which influence sediment production and delivery to rivers (see Section 3.2, Equation 1, and Appendix A1).

While the study analyzed sediment production and transport across both spatial (catchment-scale) and temporal (monthly/annual) scales, the focus on average behavior was necessary to capture basin-wide trends over the 30-year period. However, temporal land use dynamics were explicitly incorporated in the simulation, particularly in the analysis of sediment behavior (see Figure 11). These dynamics helped explain variations in sediment production and transport, with land use changes like deforestation and agricultural expansion leading to increased erosion, especially in regions such as southern Brazil and the Andes.

Incorporating land use changes significantly improved model performance, as these changes directly affected sediment dynamics. For instance, areas undergoing deforestation exhibited higher sediment output due to reduced vegetation cover, which is consistent with observed trends in soil erosion (see Section 4.1, Figure 5). This dynamic inclusion of land use changes provided a more accurate representation of sediment transport and helped explain regional differences in sediment behavior.

- **Similarly, it would have been interesting to include more of the results from reservoir sedimentation. In my opinion, it is not necessary to provide these analyses for the publishing of the manuscript, it is sufficient to change the existing language to state that these analyses can be potentially done in the future and move them to a relevant section.**

Answer:

Thank you for your valuable suggestion regarding including more results on reservoir sedimentation. We agree that further analyses on this topic would indeed be interesting and could provide additional insights into the role of reservoirs in sediment dynamics across the basin.

However, as the focus of this study was on validating the model and understanding the current sediment transport patterns, we have chosen to limit the scope of reservoir analyses in this manuscript. Moving forward, our future work will prioritize applying the model to scenario analyses to simulate the impacts of climate change and land use change on sediment yield in the Amazon

Basin. These scenarios will provide insights into how sediment dynamics may evolve under changing environmental conditions, including the role of reservoirs in mitigating or amplifying sediment transport.

Specific comments:

- **Authors use "water bodies" to mean lakes and reservoirs. Often this term includes also rivers. It would be good to define the term at the first use.**

  Answer:

  We will define the term clearly at its first use in the manuscript.

- **27-30: it is not clear how "the hydrological response as a result of climate change" links to the rest of the sentence. I would recommend breaking it down and rephrasing**

Answer:

Thank you for your comment. To address the reviewer's suggestion, we will rephrase the sentence for better clarity. Here's the revised version:

"The Amazon forest also plays a crucial role in the global climate system by absorbing solar energy and recycling half of the regional rainfall (Marengo et al., 2011). However, it is threatened by deforestation, which could increase the export of suspended sediment and nutrients to the ocean. Additionally, climate change may further impact the hydrological response, influencing sediment transport, which is vital for agriculture downstream and the survival of important fluvial and coastal ecosystems."

- **80-81: please verify units for the discharge**

Answer:

Thank you for your comment. The units for the discharge in lines 80-81 will be verified. Based on the context, the discharge is most likely reported as km^2/year.

- **Section 3.1. Methods are missing to specify how the hydrological processes were calculated (i.e., infiltration, evapotranspiration, percolation, …)**

Answer:

Thank you for your comment regarding the hydrological processes in Section 3.1, particularly concerning infiltration, evapotranspiration, and percolation. We agree that further details on how these processes were calculated would help clarify the model methodology.

The specific calculations for infiltration, evapotranspiration, and percolation are detailed in the works of van Beek and Bierkens (2009), which describe the PCRGLOB-WB model, the hydrological framework that our study builds upon. These references provide in-depth explanations of the methods used to compute these processes, which involve daily precipitation being split into surface runoff and infiltration, with infiltrated water either contributing to soil moisture, evapotranspiration, or percolation toward groundwater. Once the water reaches the groundwater, it is routed as baseflow. Calculations and methods related to these processes are extensively covered in these papers, we chose not to repeat them in our manuscript to avoid redundancy and keep the manuscript concise. However, we have revised the manuscript to reference these works explicitly and direct the reader to these sources for a comprehensive explanation.

"The detailed methods for calculating hydrological processes such as infiltration, evapotranspiration, and percolation are described in van Beek and Bierkens (2009) and Sutanudjaja et al. (2018), which form the basis of the PCRGLOB-WB model used in this study. To avoid repetition, we refer the reader to these works for a complete description of the calculations involved in the water balance computations and related hydrological processes."

- **93-94,138: one states that forcing data is taken from global datasets, another says Hybam**

Answer :

Thank you for your comment. We would like to clarify that, as stated in line 138, only precipitation data was taken from the Hybam database:
"For the Amazon, existing global datasets often have a dry bias, leading to underestimation of the discharge. In order to remove this bias, precipitation data were taken from the Hybam database, which provides daily raster precipitation maps with a $1 \times 1^{\circ}$ spatial resolution."

- **eq.1 last term should be P, not Y**

Answer:

Thank you for your comment. We will update Equation 1 by replacing "Y" with "P" as suggested.

- **Section 3.3. I would recommend reordering some of the formula descriptions (especially from l.214) so it follows a more logical order. It works better for the reader to start from the higher level equations and work step by step into details. E.g., start with Suptake (eq.9-10), then TC (eq 8).**

Answer:

We will start with Suptake (Equations 9-10) and then proceed to TC (Equation 8), as recommended.

- **Similarly l.235-240. Overall, I'd recommend a thorough review of formulas and symbols. I found several mistakes but might have missed some also.**

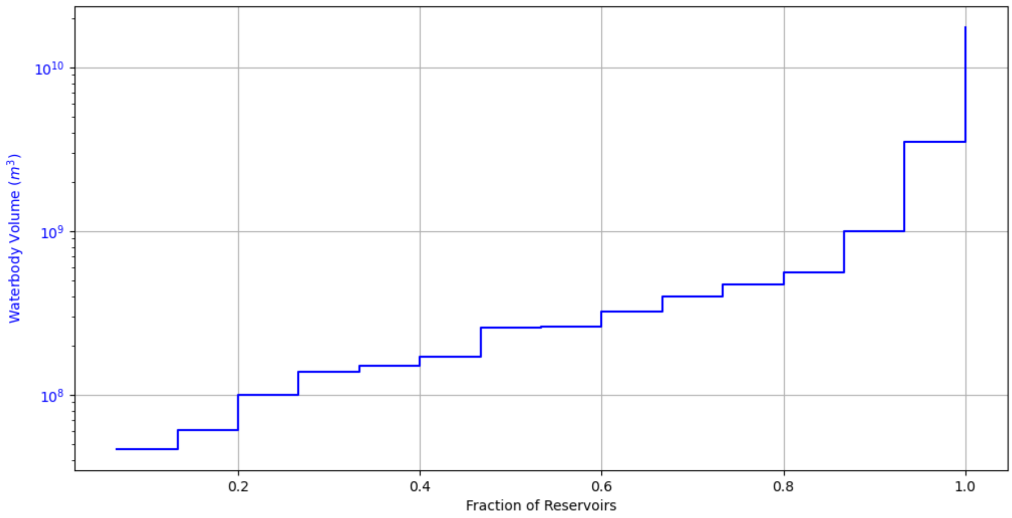
  Answer:

We will conduct a comprehensive review to correct any identified mistakes and ensure consistency across all equations and symbols.

- **Figure 4: it may help to show y-axis on a log-10 basis. Also, the caption states that "the curve rises steeply at first … and it levels off (later)". I see it as opposite: the curve rises slowly at first with a sharp rise at the end with only a few large reservoirs. It may be interesting to add another line for lakes.**

  Answer:

We agree that presenting the y-axis on a log-10 scale could improve the visualization of the reservoir distribution, particularly for illustrating the disparity between the contributions of small and large reservoirs. We will test this adjustment and incorporate it if it enhances clarity.



Regarding the description of the curve, you are correct. Upon review, the curve initially rises slowly, representing the many small reservoirs with limited capacity. The sharp rise at the end reflects the substantial contribution of a few large reservoirs to the total capacity. We will revise the caption to accurately describe this pattern.

- **Eq.6: please check the units considering the inclusion of the time step. Stot is in kg, but so is Sload while Suptake is in kg/s**

  Answer:

  Regarding Equation 6, we will adjust the unit for Stot to kg/s to align with Suptake.

- **Eq. 9, l. 223, 227: why include SUF if it's assumed 1? I would also question this assumption in a basing with significant land use changes where flow and sediment regime may also be changing**

  Answer:

Thank you for your comment regarding SUF in Eq. 9. We chose to set SUF = 1 to reflect the assumption that deposited sediment is fully available for re-erosion, a standard simplification in large-scale sediment transport modeling. This simplification is widely used in sediment transport modeling to reflect scenarios where sediment deposition does not significantly alter the re-erosion potential of the channel bed.

Significant land use changes may indeed alter sediment characteristics, such as particle size, cohesion, or compaction, which could affect sediment re-uptake. However, the scale of this study prioritizes capturing overall sediment flux patterns rather than localized sediment behavior. The assumption of SUF = 1 provides a reasonable baseline for basin-scale dynamics. Future applications of the model could incorporate adjusted SUF values if site-specific data or calibration justifies deviations from this assumption.

- **Eq.11: should V be Vs? V is previously used as water volume in eq.7.**

  Answer:

  Thank you for pointing this out. You are correct that V in Equation 11 will be replaced with Vs to avoid confusion, as V was previously used to denote water volume in Equation 7.

- **Eq15: RA not defined, instead Awb is listed on l.242**

  Answer:

  Thank you for your comment. You are correct that RA in Eq. 15 should be replaced with Awb, as defined in line 242. While the correction was made in the text, it was not updated in the equation. We will revise Eq.15 to replace RA with Awb.

- **245: how was the model parameterized?**

Answer:

Thank you for your comment. In this case, land use was parameterized using global datasets such as those from the PCRGLOB-WB, which includes the Global Land Cover Characterization (GLCC) Version 2 dataset provided by the USGS Eros Data Center (2002).

Similarly, the reservoirs were parameterized using the HydroLakes dataset, which provides comprehensive information on the locations and characteristics of lakes and reservoirs worldwide. This dataset is referenced in the manuscript in Table F1 and under Figure 3 (Messager et al., 2016).

- **273: abRMSE not listed here but shown later**

  <u>*Answer:*</u>

  Thank you for your comment. The equation for abRMSE is already included in the manuscript; however, we will add abRMSE to the list of model performance evaluation tools in the text, providing context and a clear introduction to its use.

- **Eq.22: this is shown without context or introductory text.**

  <u>*Answer:*</u>

  See previous answer

- **Eq.23: I'm not sure I understand the intent here. Sediment production is a sum of erosion and sediment delivered to the river in the catchment (Sdel). What exactly is meant by Sdel? Is this not a portion of A?**

<u>*Answer:*</u>

Thank you for your comment. Equation 23 defines the annual sediment production in the catchment (Spro) as the sum of total soil loss (∑A) and sediment delivered to the river (∑Sdel). While it is true that Sdel is a portion of A, it is explicitly separated in the equation to represent the fraction of sediment that transitions from hillslope erosion to the river system. This distinction is crucial for sediment transport modeling, as it captures the sediment that actually contributes to the river's sediment load.

By separating Sdel, we ensure that all sediment sources are accounted for, with Sdel specifically highlighting the portion of erosion that reaches the river. Thus, Equation 23 provides a comprehensive representation of the total sediment available for transport within the catchment, ensuring that both soil loss and sediment transport processes are appropriately captured.

- **310 – should this be Figure 5?**

  Answer:

  Thank you for your comment. You are correct; the reference should be to Figure 1, not Figure 5. We will make this correction in the manuscript to ensure accuracy and consistency

- **Figure 5: please add catchment boundaries and a legend explaining the lines**

  Answer:

Thank you for your comment. We understand your request to add catchment boundaries and a legend explaining the lines in Figure 5. However, we have already described the catchment boundaries in Figure 1, and including them again in Figure 5 results in an overly cluttered figure. To avoid redundancy, we believe the current version of Figure 5 remains clear without the catchment boundaries.

We will, however, ensure that the legend in Figure 5 is sufficiently detailed to explain the lines and other elements, so that the figure remains comprehensible without the additional boundaries.

- **325 "Because …" – incomplete sentence**

  Answer:

Thank you for your comment. We acknowledge that the sentence in line 325 was incomplete. The corrected sentence is: "Because of the lack of available rainfall gauges in the western region (Andean sub-basins) of the Amazon (Hoch et al., 2017).

- **figure 9: It appears that for Manacapuru and Tabatinga there are some differences in seasonality for discharges and sediment transport. Observed discharge peaks in May – June while sediment transport behaves very differently. I assume this is directly related to estimating monthly sediment transport from one or two observed data points and does not represent reality.**

Answer:

Thank you for your comment. The differences in seasonality for discharge and sediment transport at Manacapuru and Tabatinga in Figure 9 likely stem from limitations in the observational data used to calculate sediment transport, as mentioned in the manuscript. Specifically: " In the Hybam dataset, sediment concentration was typically sampled every ten days or three times a month at fixed positions near the middle of the river. However, the number of samples available was sparse, with significant gaps in coverage for some years. For example, at Tabatinga, only one sample was collected in 1995 and one in 1997, with no samples available for 1996, 2008, and 2009. Similarly, Manacapuru experienced sparse data in certain years, such as 1995". This low sampling frequency means that sediment transport estimates were often extrapolated from only one or two data points per month, which introduces uncertainties and may not accurately reflect the true seasonal dynamics of sediment transport as it is mentioned in the manuscript "To make use of the sparse observations and to facilitate the comparison between the observed and simulated values, the following steps were taken to calculate the observed monthly and annual suspended sediment transport"

Furthermore, the sediment transport process is inherently complex and influenced by multiple factors beyond discharge, such as sediment availability, deposition, and transport capacity, which are not directly tied to hydrological peaks. The modeling framework integrates sediment production, delivery, and deposition processes but does not account for some fine-scale dynamics, such as bank erosion or floodplain deposition, which can further contribute to differences in observed and modeled seasonality. Addressing these limitations would require more frequent and spatially distributed sediment concentration measurements to improve the reliability of monthly transport estimates and better align with the seasonal patterns observed in discharge.

- **Figure 10 caption: the inflow is on the left side, not on the right, and vice versa for outflow.**

Answer:

Thank you for your observation. Upon reviewing the figure caption and the associated content in the manuscript, it appears that the inflow and outflow sides were mislabeled. The caption should correctly state that the inflow is on the left side and the outflow is on the right side. This error will be corrected to ensure clarity and alignment with the figure.

- **l. 386: it should be KGE <= -0.41 implies no skill / baseline, although optimal KGE would be of course higher**

  Answer:

Thank you for your comment. We agree with your suggestion. We will revise the manuscript to clarify that KGE ≤ -0.41 implies no skill, as the KGE value is low. The sentence will be updated from:

"reflected in the skill of the model, as the KGE is low (KGE ≤ 0.414 does imply no skill at all)"
to:
"KGE ≤ -0.41 implies no skill / baseline, although the optimal KGE would of course be higher."

- **393: I would argue that figure 11 does not show impacts of climate and land cover variations, at least not specifically. Generally it shows changes in time that can be due to these and other changes. I recommend rephrasing the statement. Impact of reservoirs can potentially be implied from the slope depending on what is shown in the figure (see below).**

  Answer:

Thank you for your valuable feedback. We agree with your point and will rephrase the statement as follows:

"Figure 11 shows temporal changes in sediment transport, which may be influenced by various factors, including climate change, land cover variations, and reservoir impacts. However, these changes are not specifically isolated in the figure. The slope of the trend could potentially reflect the impact of reservoirs, among other influences."

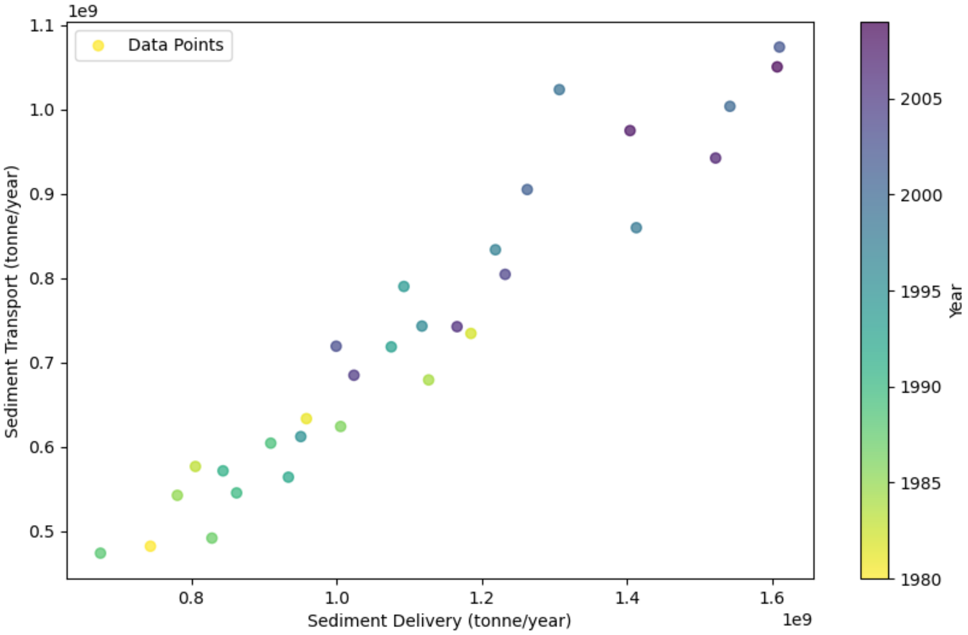
- **Figure 11. The figure labels say sediment delivery while the caption says sediment production. It is unclear if all points are for the same location (and which one, total transport from Amazon?) or for selected**

stations. Sediment transport is 3-9x1011 t/yr while sediment transport in Table 3-5 is in the order of 108 t/yr. What is marked as "sediment delivery" is in the order of 109 t/yr.

Answer:

Thank you for your insightful comment. You are correct, and we appreciate you pointing out the discrepancies.

The discrepancy in the figure labels is indeed a typo. We will correct the description in the caption from "sediment production" to "sediment delivery" to match the figure.



To clarify, the sediment delivered in the figure was computed by summing the monthly data across all the grid points, which was done using the CDO fldsum command. This method aggregates the sediment data across the entire spatial domain. We will add this explanation to the figure caption to ensure the methodology is clear to readers.

Additionally, you are right about the difference in sediment transport values. The values in the figure are in kg (per year), while the values in Table 3-5 are in tons. We will convert the sediment transport values in the figure from kg to tonnes per year to align with the units used in the rest of the manuscript and make the figure more consistent.

- **Conclusions: For increased readability I would recommend to move paragraph 4 (“RDSM computes…”) to paragraph 2 before the existing single sentence (“The analyses…”).**

  Answer:

  Thank you for your comment regarding the structure of the conclusion. We agree that moving the paragraph about the model’s computation of sediment transport to the ocean (Paragraph 4) earlier in the conclusion would enhance the readability. We will revise the conclusion as suggested, and the new structure will be as follows:

“This paper introduces the River Discharge and Sediment Model (RDSM), which incorporates reservoirs and their trapping efficiency and accounts for the impacts of land use in the Amazon. We applied the model at a spatial resolution of 5 arc-minutes over the period 1980–2009. We validated it in terms of discharge and sediment transport using the Hybam database for seven gauging stations on the mainstream Amazon and its tributaries. We also compared the sediment transported to the ocean in our model to simulations from previous studies. Our model covers different spatial scales and links soil loss at the hillslope scale to sediment entrapment and uptake along the river to the transport to the ocean. Information on each of these aspects and their connections 410 are important to assess the effects of erosion for farming, of sediment transport and fragmentation for environmental purposes, and for the stability of the Amazon estuary and coasts.

RDSM computes sediment transport to the ocean at 5.96×10^8 tonnes per year. It agrees with field measurements and has small differences with previous studies due to the trapping efficiency impacts. The RDSM effectively represents the patterns of 420 monthly and annual variations of discharge and sediment transport at 5 arc minutes resolution in the Amazon basin and to the ocean.

The analyses of the sediment in the basin shows that the catchment of Tabatinga had the highest sediment production followed by the catchments of Portovelho, Serrinha and Caracarai. Our analysis shows that the annual and monthly simulated discharge values agreed at most of the stations with reported values, with KGE values between 0.57 415 and 0.92. Further, the annual values for sediment transport shows agreement with the simulated values in most of the stations. Monthly and annual modelled sediment transport overestimated some stations compared to the Hybam observations, with KGE values between −1.7 and 0.49.

- **426: Perhaps modify to say “bank and channel erosion”.**

Answer:

Thank you for your suggestion. We agree that using the term “bank and channel erosion” is more accurate.