We thank the anonymous reviewers for the constructive suggestions and comments. Below, we provide point-by-point responses to each comment. Our replies are introduced by "Response:". Text highlighted in blue indicates revisions that are incorporated into the revised manuscript.

Reviewer 1

The study provides a comprehensive and timely analysis of the alterations in flow regime in the Mekong mainstream and their intricate, yet crucial linkage with the Tonle Sap Lake system, both of which have entered a critical phase of change under dam regulation and climate change. This study offers a new perspective on the changes in river flow regime and river-lake connectivity through alternative hydrological metrics, flow extremes, and the response time, as well as reverse flow periods. While the methodology is robust and the conclusions are generally well-supported, several key concerns require clarification and improvement for better readability and scientific rigor. Please find my specific and minor comments as follows.

Response: The authors thank the reviewer for the positive comments, feedback, and suggestions. Please find our replies to each comment below.

Specific comments:

1. L109-L113: Since the study importantly points to the Mekong River-Tonle Sap Lake dynamics, more numerical details on the hydrology/hydrodynamics of the lake are necessary. For instance, Tonle Sap Lake is also contributed by the Tonle Sap tributaries to an extent that is, however, less than the reverse flow contribution.

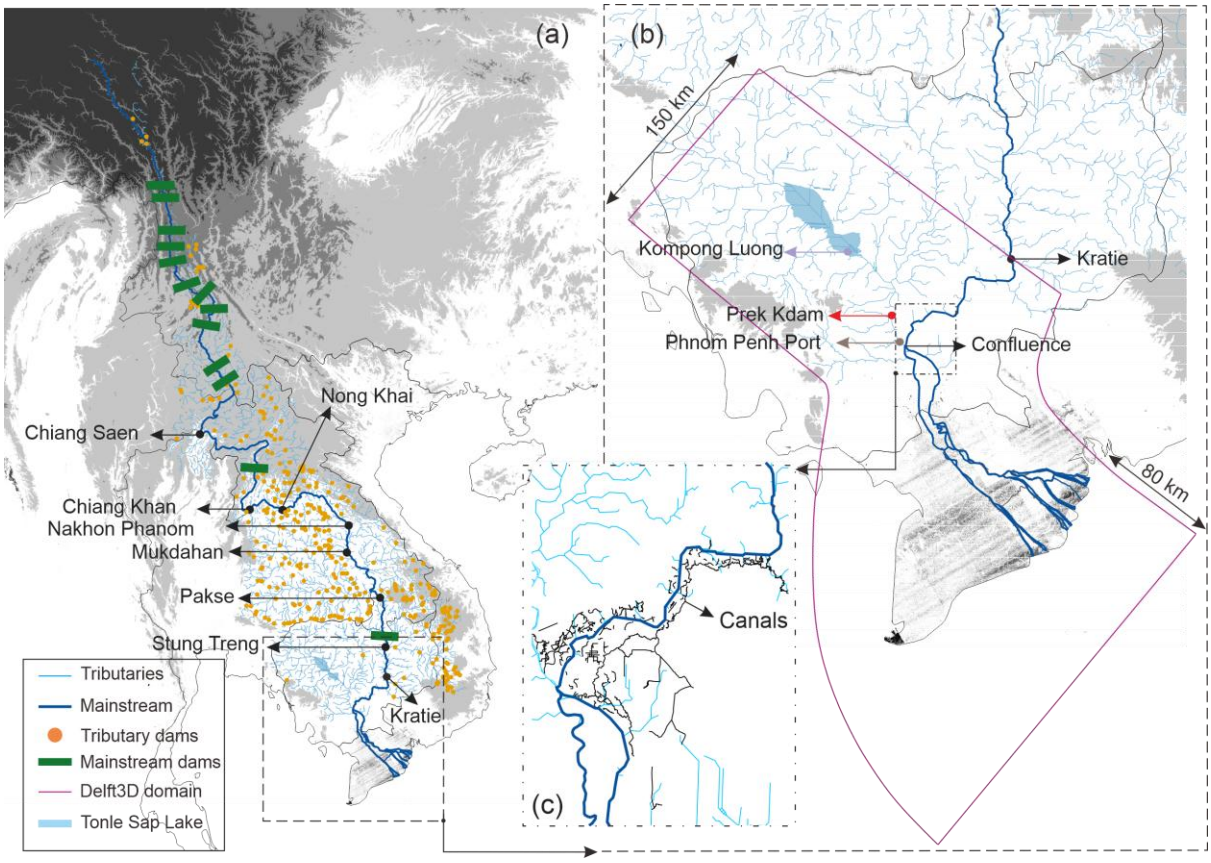
Response: We thank the reviewer for this helpful suggestion. We agree that, given the central role of Mekong-Tonle Sap coupling in our study, the manuscript should provide clearer quantitative context on Tonle Sap Lake hydrology and the relative magnitude of its inflow components. Accordingly, we added the following information to the revised manuscript (see revied manuscript, lines 128 to 137).

"Downstream, the Mekong River interacts seasonally with the Tonle Sap Lake via the Tonle Sap River. During the wet season, elevated mainstream water levels reverse the hydraulic gradient at the confluence and drive reverse flow into the lake, expanding its surface area from ~2,500 km² in the dry season to > 13,000 km² at peak inundation (Kummu et al., 2014; Morovati et al., 2023). Lake water level typically rises from ~1.2 to 10.4 m (Dang et al., 2022), corresponding to a storage increase of ~1.6-59.7 km³ (Kummu et al., 2014; Morovati et al., 2023). Water-balance analyses indicate that the Mekong mainstream (via reverse flow) supplies the dominant fraction of annual inflow (~42-53.5%), while Tonle Sap tributaries contribute a smaller but substantial share (~34-41%), and direct precipitation contributes ~12.5% (Kummu et al., 2014; Morovati et al., 2023). This seasonal exchange delivers sediment- and nutrient-rich water that underpins floodplain productivity, supporting one of the world's most productive freshwater fisheries and sustaining Cambodia's rice-based agrarian economy.

.”

2. Section 2.2: The section did not list Phnom Penh Port station, while Figure 1 depicts it. What is the role of the station in the study? Even if the station's location is used, not the hydrological data, how it was used should be clarified.

Response. Thank you for pointing this out. The Phnom Penh Port was not used for flow regime analysis. It was included only to indicate the station location for the cross-section validation in Figure S1, where we compare the interpolated cross-section with the measured cross-section. Please see the revised Figure 1 caption (lines 139-144 of the revised manuscript), where we clarify how this station is used.



“Figure 1. Map of the Mekong River basin and model configuration. (a) Locations of the Mekong mainstream and tributary network, hydrological stations, and mainstream and tributary dams. (b) Computational domain of the Delft3D-Flow hydrodynamic model, highlighting key sites (e.g., Kratie, Kompong Luong, and Prek Kdam). (c) The canal network between Kratie and the Tonle Sap-Mekong confluence incorporated in the model to represent floodplain connectivity and exchange via the Tonle Sap River. Note: The Phnom Penh Port station is shown for reference and is used only for river cross-section validation (Fig. S1), not for the flow regime analysis.”

3. Section 2.3: Weather data for the THREW model were not introduced. Please provide the details and sources of all input data for the hydrological and hydrodynamic models.

Response: Thank you for this comment. We have clarified the variables and data sources used to force THREW–precipitation, temperature, and Penman-Monteith potential evapotranspiration–as well as the land-surface and vegetation datasets used for model parameterization (e.g., soil properties and MODIS-based vegetation/snow products). In the revised manuscript, we added these details in Sections 2.4, 2.5.1, and 2.5.2, as follows.

(Section 2.4): *"The THREW hydrological simulations were driven by station-based precipitation and meteorological observations from the MRC and the China Meteorological Administration (CMA). Precipitation was obtained from a basin-wide gauge network (105 stations) and air temperature from 35 stations (Fig. S3 in the Supplement). Daily potential evapotranspiration was computed using the Penman-Monteith method based on station meteorological variables (including temperature, wind speed, humidity, and radiation/sunshine duration). Soil properties were taken from the FAO global soil database (10 km). Vegetation and surface-condition inputs (NDVI, LAI, and snow cover) were derived from MODIS products (500 m, 16-day) following Zhang et al. (2023)."*

(Section 2.5.2): *"Bathymetry was derived from the surveyed cross-sections (spacing 300-3,000 m) using the interpolation procedure described in Sect. 2.4 and mapped to the Delft3D curvilinear grid with Delft3D-QUICKIN (triangular interpolation with internal diffusion). Interpolation performance, assessed via leave-one-section-out cross-validation and independent-transect comparisons, achieved an RMSE of 0.46 m and a median absolute error of 0.37 m."*

4. Section 2.4: This section should appear before Data Sources and Preprocessing, as it gives precedent information on changing morphology in the segregated periods.

Response: Thank you for this helpful suggestion. We agree and have moved the period-classification section to precede "Data sources and preprocessing" as Section 2.3 to improve the logical flow and readability (see revised manuscript, line 153).

5. L187: Is a one-year warm-up period good enough to initialize the model, given the complex system? Should there be any potential limitations pertaining to this setup?

Response: Thank you for raising this point. We agree that the adequacy of a warm-up period should be justified for a coupled river-lake-floodplain system. We used **a one-year warm-up** because it comfortably exceeds the dominant **hydrodynamic adjustment timescales** of the system and includes a full seasonal cycle (dry-to-wet transition, flood rise, and recession), which is essential for initializing storage and exchange fluxes.

First, our response time analysis (Fig. 5a) indicates that the propagation time of mainstream flow from Kratie to the confluence is ~1-14 days, depending on discharge (see Fig. 5). This short hydraulic response implies that boundary perturbations and initial condition effects are rapidly flushed from the river network relative to a one-year spin-up.

Second, the lake-floodplain component requires initialization of seasonal storage dynamics. A one-year warm-up explicitly contains one complete flood pulse, allowing lake level, inundation extent, and exchange flows to adjust consistently to the model physics and boundary forcing. Consistent with this, our prior Tonle Sap Lake modelling work used a 3-month warm-up and

found it sufficient for stabilizing lake dynamics, even though that domain was smaller than in the present study (Morovati et al., 2023). The longer one-year warm-up adopted here is therefore a conservative choice.
Third, we empirically verify adequacy by examining model performance **immediately after the warm-up year**. If the spin-up were insufficient, the following year would typically show systematic bias or transient drift in simulated water levels. However, the model achieves high accuracy in 2010 when 2009 is treated as the warm-up year (Supplementary Fig. S5), indicating that initial-condition sensitivity has largely decayed.
Fourth, consistent with the reported model accuracy for simulating the reverse flow period, the timing error is small–within 0-3 days across the evaluation years (see Table S3 in Supplement). For 2010, the simulated reverse flow period differs by only 1 day relative to the period reported by the MRC.

6. Sections 2.5.1, 2.5.2, and 2.5.3: I believe the order of the three sections should be reorganized, as the development of the hydrological model is crucial as the boundary condition for the hydrodynamic model, and then the response model was embedded in the hydrodynamic framework. This is also in line with the order of the analyses.

Response: Thank you for this helpful suggestion. We agree and have reordered Sections 2.5.1-2.5.3 to follow the model dependency chain: THREW hydrological model (Section, 2.5.1) → Delft3D-Flow model (Section 2.5.2) → response-time model (Section, 2.5.3). We also corrected internal cross-references so that tributary inflows and naturalized discharge are now consistently referenced to the hydrological model section. Thank you.

7. Section 2.5.2: The response time model is for the stretch between Kratie and the Mekong-Tonle Sap confluence, which is in Phnom Penh, specifically at the Phnom Penh Port location. However, it was stated in Section 2.2 that Prek Kdam and Kompong Loung were listed for hydrodynamic validation and also discharge lag adjustment, implying that either station was considered for adjusting the discharge lags. Please clarify both sections.

Response: Thank you for noting this. The response-time (water-age) model quantifies lag from Kratie to the Mekong-Tonle Sap confluence (revised manuscript, line 281), which is the hydraulic control point governing reversal of the Tonle Sap River. The Phnom Penh Port gauge is nearby but not identical to the confluence; (located on the Tonle Sap River ~4 km from the confluence). As shown in the revised Figure 1b, Phnom Penh Port lies between Prek Kdam and the confluence.
Prek Kdam and Kompong Luong were included for hydrodynamic model validation and to characterize river-lake exchange, rather than as the target location for lag adjustment (see revised manuscript, lines **281–285**; Figure 1 caption; and Section 2.5.2, line 265). For example, in "Response time model", the related discussion reads as follows (lines 283-285):

*"The concept of response time, also referred to as water age, reflects the transit time required for water parcels to travel from a specified upstream point to a downstream target location (Morovati et al., 2024b). It characterizes the average residence time of water traveling from the **Kratie station** (inlet boundary) to the **Mekong-Tonle Sap confluence**."*

8. L288: Higher monsoonal rainfall predominantly in the lower Mekong can also be highlighted in addition to tributary inflows.

Response: We agree and thank the reviewer for this helpful suggestion. The revised text reads as follows (revised manuscript, lines 359-361):

….. This pattern is consistent with reservoir operations strengthening persistence upstream, while monsoon-driven runoff contributions from downstream tributaries and adjacent floodplains, which become increasingly important in the lower basin modulate (and may offset) that signal.

9. Section 3.3: Some of the methods, like amplitude and peak count, should be briefly explained prior in the Method section.

Response: Thank you for this helpful suggestion. In the revised manuscript, we added a short subsection in Section 2.5 describing the computation of (i) sub-daily amplitude (daily max–min water level range), (ii) peak count (number of hourly water-level rises ≥ 0.05 m h^{-1}), and (iii) the implementation of RBI for sub-daily water level time series. The revised subsection reads as follows:

2.5.7 Sub-daily water-level variability metrics

Sub-daily water-level variability was quantified using three complementary metrics derived from 15-min water-level records (available from 2018 onward). For each day d, amplitude (A) was defined as the daily range of sub-daily water levels (WL):

$$A_d = WL_{max,d} - WL_{min,d} \quad (9)$$

Monthly amplitude was computed as the mean of A_d over all days in the month. Sub-daily flashiness was computed using the Richards–Baker formulation, substituting water level for discharge and applying the calculation within each calendar month:

$$RBI_{WL} = \frac{\sum_{i=2}^{n} |WL_i - WL_{i-1}|}{\sum_{i=1}^{n} WL_i} \quad (10)$$

where WL_i denotes consecutive 15-min observations within the month, and n is the number of valid records. This yields a dimensionless index of intramonth sub-daily variability. Peak count was defined as the number of hourly water level rises exceeding a threshold of 0.05 m h^{-1} (i.e., 5 cm h^{-1}), following the rate-of-change guidance referenced by the MRC (MRC, 2020). The 15-min series was resampled to hourly water levels. Daily peak count was reported as events per day and aggregated to monthly values by averaging across days.

10. Figure 3: The figure and its caption mention 2018-2024, but the caption also states 2017-2024. Could you elaborate on the difference?

Response: Thank you for pointing this out. In the initial submission, our sub-daily analysis used data from 2017-2024; however, 2017 observations were only available for a limited number of stations. In the revised manuscript, we obtained additional records from the MRC and extended the dataset to include 2025. To ensure consistent period coverage across all stations, we removed the incomplete 2017 data and harmonized the analysis window

accordingly. We have revised the relevant text to state that the sub-daily dataset covers 2018-2025 (e.g., revised manuscript, line 100 and 423).

11. Section 4.1: I find that this discussion section provides new major results along with their discussion. Those results are directly relevant to the topic and objectives. It makes more sense to transition those findings to the Results section; hence, this leaves more room for their implications to be expanded in the Discussion. Equally important is that previous studies should be cited in the section to enhance the interpretation of results and discussion, as the Mekong-Tonle Sap Lake connectivity has been increasingly explored with a wide range of implications beyond hydrodynamics.

Response: Thank you for this helpful suggestion. We agree that the original Section 4.1 mixed new quantitative findings with interpretation.
We moved these quantitative findings to the Results as a new subsection (**Section 3.5: *Lag-adjusted Kratie discharge thresholds for reverse-flow onset and cessation***), and we revise Section 4 to focus on interpretation and implications. In the revised Discussion, we also expand citation of previous work on Mekong-Tonle Sap connectivity and its broader implications. Please see the revised manuscript, **Section 4** (lines 499 to 558).

Minor comments:

1. L24-25: It is better to mention "one of the world's most ecologically productive river–lake systems" early in the Abstract to highlight the significance of the study area.

Response: Thank you for this suggestion. We revised the opening sentence of the Abstract, which reads as follows (see revised manuscript, line 9)

Dam construction and climate change have profoundly disrupted the hydrological dynamics of the Mekong River-Tonle Sap Lake floodplain system, one of the world's most ecologically productive river-lake complexes. This study provides an integrated, …….

2. L45 and L47: Please clearly indicate the months in the wet and dry seasons.

Response: Thank you for the suggestion. The revised text reads as follows (see revised manuscript, lines 49 to 52):

"These impacts have been especially pronounced during the dry season (November-April): Räsänen et al. (2017) reported dry season discharge increases of 121-187% at Chiang Saen, the most upstream station in our study reach, in March, and an increase of 32-46% at Kratie, the most downstream station (Fig. 1). Lu and Chua (2021) found a 98% increase in monthly discharge at Chiang Saen during the dry months. Concurrently, wet-season flows (May-October) have declined substantially (Lu et al., 2014), undermining the amplitude and timing of flood pulses that sustain floodplain ecosystems. Nguyen et al. (2025) documented a 73.7% increase in dry-season flows at Chiang Saen between 2000 and 2019, underscoring the dominant role of dam-induced regulation."

3. L46: The relative locations of Chiang Saen and Kratie stations should be addressed for the first time (i.e., the most upstream and downstream stations).

Response: Thank you for the comment. Please see the revised manuscript, lines 49 to 51:

4. L80: For the last paragraph, I noticed that sub-daily variability was not indicated, although it was analysed with its own subsection in the Results. It should be listed here in the Introduction for a full picture of the objectives.

Response: Thank you for this helpful comment. We have addressed it in the revised manuscript. The revised text now reads as follows (see revised manuscript, lines 100-101).

"…… In addition to these indicators, we examine annual discharge extremes, including maximum and minimum daily flows and their associated timing. In addition, using 15-min water-level observations (2018-2025), we quantify sub-daily variability using amplitude, flashiness (RBI), and peak count metrics. Finally, we link these altered flow characteristics to the onset, termination, and duration thresholds of Tonle Sap's reverse flow using Delft3D-Flow hydrodynamic simulations with a response-time model from Kratie to the Mekong-Tonle Sap confluence, which enables a physically consistent lag adjustment between Kratie discharge and conditions at the confluence.

5. L126: The Delft3D-Flow hydrodynamic model first appeared in Section 2.2. It would be better to mention it first in the Introduction.

Response: Thank you for the helpful suggestion. We have addressed this point in the revised manuscript (see line 102).

6. L133: (see Figure 2d–f) should be moved to the end of the sentence.

Response: Thanks for this suggestion. We have moved (see Figure 2d-f) to the end of the sentence, and read as follows (revised manuscript, line 181):

"Except for this case, our analyses reflect the compounded impacts of dam regulation and climate variability, and we do not explicitly disentangle their relative contributions (Fig. 2d-f)."

7. L140: Provide the full form of PMFM.

Response: Thanks for your comment. We have addressed this point in the revise sentence reads. The revised text now reads as follows (see revised manuscript, line 186):

For hydrodynamic analyses of the Tonle Sap system, additional time series of lake water levels, reverse flow periods, and discharge were acquired from the MRC and Procedures for the Maintenance of Flows on the Mainstream (PMFM) online platform (https://pmfm.mrcmekong.org/monitoring/6b/)

8. L180: Should (see Sect. 2.5.2) actually refer to Sect. 2.5.3? Please also verify all other cross-references.

Response: Thank you for the comment, and we apologize for the oversight. Yes, this refers to Section 2.5.3. Following the reordering in the revised manuscript, it is now correctly cited as Section 2.5.1 (rather than Section 2.5.3).

9. L192: Figure 1c should be Figure 1b. Please correct.

Response: Thank you for the comment. Yes, it should refer to Figure 1b in the original submission. However, after adding a new panel in the revised manuscript, the corresponding reference is now Figure 1c. The revised text now reads as follows (line, 273):

"To represent these flows, we extracted canal networks using a machine learning-based remote sensing model developed by Zhao et al. (2025), supplemented by manual digitization from high-resolution satellite imagery (Fig. 1c). This enabled a more realistic representation of hydraulic connectivity between rivers, floodplains, and the lake. More details can be found in Zhao et al. (2025)."

10. L239: Please mention the period of calibration and validation for the model in the main text, although this appears in the supplementary file.

Response: Thanks for the comment. We revised the text as follows (revised manuscript lines 202 to 203) (revised manuscript, lines 239 to 241):

"Model calibration was conducted using an automatic parallel computation framework that optimizes hydrological parameters across multiple REWs simultaneously (Nan et al., 2021) (Table S2 in the Supplement). This enabled efficient exploration of the parameter space while maintaining consistency with observed discharge data at available gauging stations. The THREW model was calibrated for 2000-2009 and validated for 1980-1999 using observed discharge at available gauging stations; detailed performance metrics are provided in the Supplement. The THREW model was used to simulate daily discharge for all tributaries flowing into the Mekong and the Tonle Sap Lake, providing critical boundary conditions for the hydrodynamic simulations described in Sect. 2.5.2."

11. L279: Change (a-f) to (Figure 2a-f) or (Figure 2)

Response: Thanks for the comment. We revised the text, which reads as follows (line 348):

"Six rose diagrams (Fig. 2a-f) summarize the spatiotemporal evolution of discharge dynamics across eight mainstream stations from Chiang Saen to Kratie."

12. Figure 4: The cross-reference of Figure 4d is apparently missing in the text.

Response. Thank you for noting this omission. We revise the Results text to explicitly cite Fig. 4d, which shows the timing of annual minimum discharge across stations (revised manuscript, line 456).

"The timing of annual minimum flows has consistently advanced across all stations along the Mekong mainstream (Fig. 4d)."

13. L408: Figure 6a should be 5a.

Response: Thank you for pointing out this error. We have corrected the cross-reference at line 408: "Fig. 6a" has been changed to "Fig. 5a". In the revised manuscript, this correction now appears at line 471, which reads as follows:

"Figure 5a shows (i) the nonlinear discharge-travel time relationship between Kratie and the Mekong-Tonle Sap confluence and (ii) period-specific differences in the monthly discharge regime."

14. L421 and L431: Panel 5b and Panel 5c should be addressed as Figure 5b and Figure 5c.

Response: Thank you for noting this. We have revised the text associated with Figure 5 accordingly. Please refer to the revised manuscript, Section 3.5.

15. Figure 5a: It is hard to identify the monthly average discharge during the post-dam period. Please improve the figure.

Response: Thank you for the comment. We have revised Fig. 5a to improve readability, particularly for distinguishing the monthly average discharge during the post-dam period**.** Please see the revised manusxript, Section 3.5.

Reviewer 2

The study addresses an important and timely problem by examining how hydropower development and climate change have altered the flow regime of the Mekong River. Using historical observations and a combination of hydrological and hydrodynamic modelling, the authors estimate statistical indicators of flow memory and synchrony. They show substantial post-dam changes at several mainstem gauges when compared to their pre-dam equivalents. This component of the analysis is methodologically sound, well supported by the results presented and broadly consistent with previous studies that have shown dampened wet-season flow peaks and enhanced dry-season flows under dam regulation. The attempt to link these changes in Mekong flow discharge to alterations in the reversal of the Tonle Sap River however is less convincing. The supporting results are limited relative to the strength of the claims and key relevant literature on the Tonle Sap-Mekong system is not adequately considered. As a result, the conclusions regarding reverse-flow dynamics would require more rigorous modelling and analysis to improve the manuscript. Please find my specific comments and technical corrections below:

Response: The authors thank the reviewer for the positive comments, feedback, and suggestions. Please find our replies to each comment below.

Specific comments:

The terms 'flow memory' and 'flow synchrony' are used throughout the manuscript including the title, but they are not fully introduced and their significance is not properly explained. I suggest that a short description is added in the introduction.

Response: Thank you for your helpful suggestion. We have added a brief description defining **flow memory** and **synchrony** in the Introduction and explicitly linked these concepts to the corresponding Methods sections. The revised text now reads as follows (revised manuscript, lines 56-66):

*"Most existing Mekong assessments emphasize changes in seasonal means, extremes, and selected indicators of alteration. However, such descriptors do not fully capture two properties that are central to how **basin-wide signals** propagate through **a river network and translate into downstream responses**: flow memory and flow synchrony. Here, flow memory refers to the persistence (long-range dependence) of discharge variability, that is, the extent to which present conditions retain information from antecedent fluctuations; we quantify this using the Hurst exponent (see Methods). Flow synchrony refers to the coherence of hydrograph timing and shape among stations along the mainstream, evaluated here using inter-station similarity of standardized daily discharge time series (see Methods). These properties are not simply statistical: memory affects how rapidly wet-season anomalies build and decay (and thus how predictable seasonal cues remain), while synchrony reflects how coherently the flood pulse is transmitted downstream. A decline in either property indicates hydrological fragmentation, meaning that upstream forcing becomes less persistently expressed through time and less consistently aligned across space, even when changes in mean seasonal discharge appear modest."*

Lines 21-23: The statement made here is misguided. The discharge threshold that must be exceeded in order for the Tonle Sap River to reverse its flow is governed by the geometrical characteristics of the Tonle Sap and Mekong Rivers and their confluence. These geometrical characteristics are indeed altered by sand-mining induced channel deepening. Mekong's flow discharge, which is affected by dam regulation and climate change, may control whether and for how long this threshold is exceeded but does not affect the threshold itself as implied here.

Response: Thank you for this important clarification. We agree that the physical trigger for Tonle Sap River flow reversal is governed by the local hydraulic head (stage) condition at the Mekong-Tonle Sap confluence, which is primarily controlled by channel geometry/conveyance and the associated stage-discharge relationships; these can be modified by sand-mining-driven incision. In the manuscript, the reported "discharge threshold" is the lag-adjusted Kratie discharge at which reversal is observed to initiate/cease, used as an operational proxy for the confluence stage/head condition rather than a fixed geometric constant. We have revised the Abstract, Conclusions, and the relevant Results text to make this distinction explicit. **We now state that riverbed lowering near the Mekong-Tonle Sap confluence reach increases the discharge required to attain the confluence stage associated with reversal**, whereas dam regulation and climate change mainly modulate whether and for how long this reversal-favourable condition is exceeded (through changes in hydrograph timing, persistence, etc.), thereby shortening the reverse flow season.

Abstract (revised manuscript, lines 24-30)

"Critically, the combined effects of the altered flow regime and sand mining-driven riverbed lowering have altered the conditions under which Tonle Sap flow reversal initiates. Using the lag-adjusted Kratie discharge at onset as an operational proxy for the Mekong-Tonle Sap confluence stage/head condition, we find that the median onset discharge increased from ~3,000 $m^3 s^{-1}$ (pre-dam) to ~7,000 $m^3 s^{-1}$ (post-dam), an increase of >130%. This upward shift is most consistent with incision-induced changes in local stage-discharge relationships, while dam regulation and climate change primarily modulate how frequently and how persistently the reversal-favourable hydraulic gradient is exceeded, collectively shortening the reverse flow period by 24 days compared to the pre-dam period."

Section 3.5 (revised manuscript, lines 465 to 469)

"Here, "threshold" denotes the lag-adjusted Kratie discharge associated with the observed onset and cessation of reverse flow, used as an operationally interpretable proxy for hydraulic conditions at the confluence. It is therefore influenced by local stage-discharge relations (including incision effects) and by the timing-dependent head difference between the mainstream and the lake, rather than representing a fixed geometric constant."

Conclusion (revised manuscript, lines 588 to 599)

"These mainstream alterations propagate into the Tonle Sap system, where the reverse flow period is shortened by approximately 24 days in the post-dam period compared to the pre-dam baseline as a compound outcome of altered flow regime and local geomorphic change. The hydraulic trigger for reversal at the Mekong-Tonle Sap confluence is the local stage/head

condition required to reverse the along-channel gradient, which is governed primarily by channel geometry and confluence hydraulics. Within this framework, sand mining-driven riverbed incision reduces confluence stage for a given discharge, thereby increasing the lag-adjusted Kratie discharge required to attain the confluence stage associated with reversal. Consistent with this mechanism, the median lag-adjusted Kratie discharge at reverse flow initiation increased from ~3,000 $m^3 s^{-1}$ (pre-dam) to ~7,000 $m^3 s^{-1}$ (post-dam), an increase of >130%. Superimposed on this shifted hydraulic setting, dam regulation and climate change reshape the seasonal hydrograph–dampening early wet season rises and altering flow timing and persistence–thereby reducing how frequently and how long the reversal-favourable confluence stage/head condition is exceeded. Together, these interacting drivers shorten and retime the reverse flow season."

Lines 40-50: The authors correctly argue that previous literature has already extensively studied the impacts of hydropower development on Mekong hydrology. Here also please specify the start and end of for the dry and wet seasons.

Response: Thanks for your suggestion. We have revised the text as follows (revised manuscript lines 49 and 52):

"These impacts have been especially pronounced during the dry season (November-April): Räsänen et al. (2017) reported dry season discharge increases of 121-187% at Chiang Saen, the most upstream station in our study reach, in March, and an increase of 32-46% at Kratie, the most downstream station (Fig. 1). Lu and Chua (2021) found a 98% increase in monthly discharge at Chiang Saen during the dry months. Concurrently, wet-season flows (May-October) have declined substantially (Lu et al., 2014), undermining the amplitude and timing of flood pulses that sustain floodplain ecosystems."

Lines 51-53: The authors here argue that the novelty of their study is on the incorporation of flow memory and synchrony but they do not explain this further or justify why this analysis is important.

Response: Thank you for this constructive comment. We have revised the Introduction to better justify the chosen approach and clarify how it differs from previous work. In particular, we added the following text in the revised manuscript (lines 56–66):

*"**Most existing Mekong assessments emphasize changes in seasonal means, extremes, and selected indicators of alteration**. However, such descriptors do not fully capture two properties that are central to **how basin-wide signals propagate through a river network** and translate into downstream responses: flow memory and flow synchrony. Here, flow memory refers to the persistence (long-range dependence) of discharge variability, that is, the extent to which present conditions retain information from antecedent fluctuations; we quantify this using the Hurst exponent (see Methods). Flow synchrony refers to the coherence of hydrograph timing and shape among stations along the mainstream, evaluated here using inter-station similarity of standardized daily discharge time series (see Methods). These properties are not simply statistical: memory affects how rapidly wet-season anomalies build and decay (and thus how predictable seasonal cues remain), while synchrony reflects how coherently the flood pulse is*

transmitted downstream. A decline in either property indicates hydrological fragmentation, meaning that upstream forcing becomes less persistently expressed through time and less consistently aligned across space, even when changes in mean seasonal discharge appear modest."

We also highlight the novelty of the present work in two additional sentences/paragraphs (revised manuscript, lines 67-69), emphasizing that **threshold-sensitive processes** governing the Mekong-Tonle Sap system remain underexplored.

Finally, we explain why the selected metrics are well suited for basin-wide analyses in the revised manuscript (lines 79-82).

Lines 53-66: Here the focus shifts towards the Tonle Sap River flow reversal but key literature that has studied this topic is omitted. The authors should review previous work focusing on the effects of climate change and flow modulation by dams (see for example: Wang et al., Environ. Res. Lett. 15, 0940a1 (2020); Frappart, F. et al Sci. Total Environ. 636, 1520–1533 (2018); Kummu and Sarkkula, Ambio 37, 185–192 (2008)) and sand mining (see for example: Quan L.Q. et al., Nat Sustain 8, 1455–1466 (2025)). When relevant literature is considered, the statement made in lines 63-66 is not supported.

Response: We thank the reviewer for highlighting the omission of key literature on Tonle Sap hydrological change. We have revised the Introduction (lines 72-82) to incorporate relevant prior work. We also refined the concluding sentences to avoid overstatement and to clarify that our novelty lies in **quantifying the multi-decadal evolution of discharge conditions associated with reverse flow onset and cessation**, and in **linking these shifts to basin-wide changes in flow memory and synchrony**. The revised text now reads as follows:

"Earlier work has shown that Mekong flow alteration can reduce flood-peak amplitude and shorten flood duration, with important ecological consequences for the Tonle Sap flood pulse (Kummu and Sarkkula, 2008). Climate variability further exerts strong control on Tonle Sap storage, with lake-volume anomalies closely tracking rainy-season rainfall anomalies across the Mekong Basin (Frappart et al., 2018), and satellite-based analyses indicate that interannual inundation fluctuations are dominated by precipitation variability, while the contribution attributed to dams constructed in China is comparatively small (Wang et al., 2020). More recently, geomorphic change near the confluence has been identified as a major control: sand-mining-driven riverbed lowering of the Mekong mainstream reduced reverse flow by ~40-50% between 1998 and 2018 (Quan et al., 2025). Building on these advances, a key remaining empirical gap is to quantify how the discharge conditions associated with the onset and cessation of reverse flow have shifted over multiple decades, and to link those threshold shifts to basin-wide reorganization of flow persistence (memory) and spatial coherence (synchrony) observed along the mainstream."

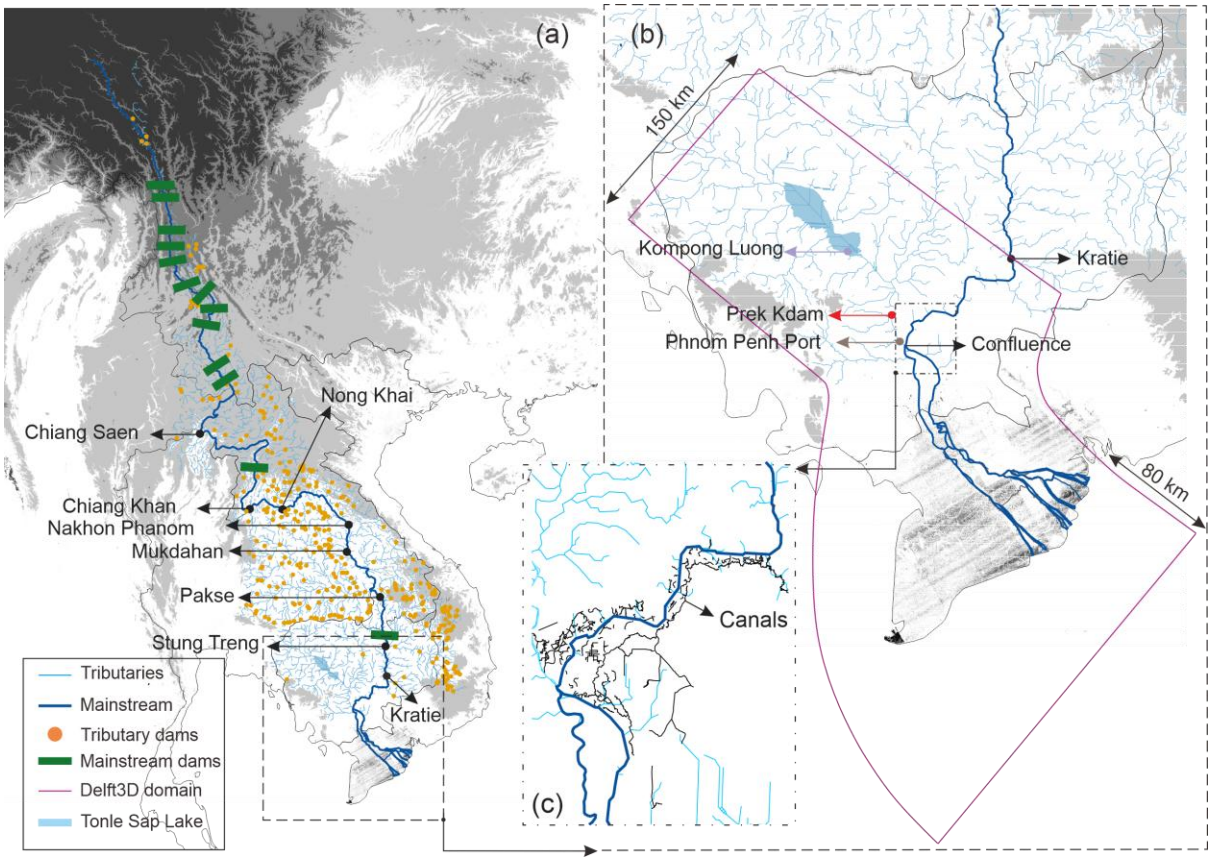
Line 131: Please specify the quality checks that were applied to the data, what proportion of the data did not pass the quality control and how were these values replaced.

Response: Thank you for this comment. We have now explicitly documented the completeness check and gap-filling procedure for the daily discharge records. For each station, we constructed a continuous daily time series for 1976-01-01 to 2024-12-31 (n = 17,898 days) and identified missing dates by comparison against the complete daily index. Missing values were rare (0-9 days per station; maximum at Kratie: 9 days, i.e., 0.050% of the record). Across the eight stations, a total of 18 station-day entries were missing, representing 0.0126% of all station-day values (18 / (17,898 × 8)). Isolated one-day gaps were filled by linear interpolation between adjacent days. For the only multi-day gap (Kratie, 2003-01-24 to 2003-01-28), discharge was infilled using the upstream station (Stung Treng) plus the intervening tributary inflow between Stung Treng and Kratie derived from the THREW model. Because the hydrological model demonstrates high skill in reproducing tributary inflows, this approach provides a physically consistent reconstruction of the missing segment (see Morovati et al., 2024b). We also added a supplementary table (**Table S1 in the Supplement**) listing all missing dates and the infilling method applied (revised manuscript, lines 170–176).

"Daily discharge data spanning 1976-2024 were obtained from the MRC Data Portal (https://portal.mrcmekong.org/home). Quality checks were applied to remove duplicates, missing dates, and outliers. For each station, we constructed a continuous daily time series (n=17,898 days) and identified missing dates by comparison with the full daily index. Missing records were rare (0–9 days per station; maximum at Kratie: 9 days = 0.050% of the record), totaling 18 missing station-day entries across eight stations (0.0126% of all station-day values). Isolated one-day gaps were filled by linear interpolation between adjacent days. The only multi-day gap (Kratie, 2003-01-24 to 2003-01-28) was infilled using the upstream station discharge at Stung Treng plus intervening tributary inflow between Stung Treng and Kratie derived from the THREW model (Table. S1 in the Supplement)."

Line 171: Figure 1 does not show the Delft 3D model domain, I suggest making a separate figure for this.

Response: Thank you for the comment. We have added a new figure that explicitly shows the Delft3D-Flow computational domain.



"Figure 1. Map of the Mekong River basin and model configuration. (a) Locations of the Mekong mainstream and tributary network, hydrological stations, and mainstream and tributary dams. (b) Computational domain of the Delft3D-Flow hydrodynamic model, highlighting key sites (e.g., Kratie, Kompong Luong, and Prek Kdam). (c) Canal network between Kratie and the Tonle Sap-Mekong confluence incorporated in the model to represent floodplain connectivity and exchange via the Tonle Sap River. Note: The Phnom Penh Port station is shown for reference and is used only for river cross-section validation (Fig. S1), not for the flow regime analysis."

Lines 195-196: Please specify the distance between neighbouring cross-sections. This could improve confidence in the bathymetric interpolation that was applied.

Response: Thank you for this helpful suggestion. We have now quantified the along-channel distance between neighbouring measured cross-sections in Section 2.4. We also clarify that the measured cross-sections were densified by generating **30-200 virtual cross-sections** between each pair of adjacent surveyed transects using a **chainage-based parameter interpolation** scheme, prior to mapping the bathymetry onto the Delft3D curvilinear grid (Section 2.4 and Supplement Section S1). These revisions make the interpolation density and underlying assumptions explicit. The added text reads as follows:

Section 2.4 (Data sources and preprocessing), lines 198 to 208:

"Adjacent measured transects are irregularly spaced along the thalweg (300 to 3,000 m). To derive a hydraulically consistent continuous bathymetry from these discrete transects, we reconstructed intermediate cross-sections in a curvilinear reference frame defined by the river

centreline (chainage) and signed cross-channel distance. For each transect, we fit a third-order polynomial bed profile and extracted left- and right-bank elevations; the resulting profile parameters were interpolated along chainage using monotone piecewise-cubic interpolation (PCHIP). Between each pair of measured transects, we generated 30-200 virtual cross-sections (~100 points per transect), enforcing (i) bank anchoring at the interpolated bank elevations and (ii) envelope clipping that constrains interior bed elevations to the min-max range of the bracketing surveyed transects. We also applied a smoothness constraint to suppress unrealistic lateral jumps in the thalweg. The measured and virtual cross-sections were then mapped onto the Delft3D curvilinear grid using Delft3D-QUICKIN, which applies triangular interpolation and internal diffusion to generate a continuous DEM at each grid-node corner (see Sect. 2 in the Supplement for more details)."

Lines 200-203: Could you show how well does the derived DEM approximate natural river and lake morphology. Can the error be quantified? It should be noted here that the supplement provides only a single cross-section as an example of good fit (Figure S1).

Response: Thank you for the comment. We have added additional details on the accuracy of our riverbed interpolation. We evaluated the interpolation against measured geometry at several cross-sections; however, because most of these surveyed transects are located within the delta, we chose to present only the Phnom Penh Port cross-section, which is more directly relevant to this study's focus on the Mekong-Tonle Sap system. The interpolation skill at the other validation sites is comparable to–and in several cases better than–that shown for Phnom Penh Port. To address your suggestion, we added the following text in the revised manuscript (lines 276-279):

"Bathymetry was derived from the surveyed cross-sections (spacing 300-3,000 m) using the interpolation procedure described in Sect. 2.4 and mapped to the Delft3D curvilinear grid with Delft3D-QUICKIN (triangular interpolation with internal diffusion). Interpolation performance, assessed via leave-one-section-out cross-validation and independent-transect comparisons, achieved an RMSE of 0.46 m and a median absolute error of 0.37 m."

Lines 234-238: Please provide more detailed information on the data that were used in the hydrological model, including sources.

Response: Thank you for this comment. We have added additional details on the datasets used to force and parameterize the hydrological model. Please refer to the revised manuscript, Sections 2.4 and 2.5.1. For example, in section 2.5.1, the following details were added (lines, 226 to 232).

"The THREW hydrological simulations were driven by station-based precipitation and meteorological observations from the MRC and the China Meteorological Administration (CMA). Precipitation was obtained from a basin-wide gauge network (105 stations) and air temperature from 35 stations (Fig. S3 in the Supplement). Daily potential evapotranspiration was computed using the Penman-Monteith method based on station meteorological variables (including temperature, wind speed, humidity, and radiation/sunshine duration). Soil properties were taken from the FAO global soil database (10 km). Vegetation and surface-

condition inputs (NDVI, LAI, and snow cover) were derived from MODIS products (500 m, 16-day) following Zhang et al. (2023).”

Lines 276-277: The manuscript here refers to the supplement for detailed validation of the models used in the study. Figure S5 of the supplement shows that on some occasions the model underpredicts peak discharge values for Kompong Luong while simultaneously overpredicting for Prek Kdam (the opposite also occurs), what are the implications of these discrepancies for the simulated hydraulic head and the reversal of the Tonle Sap River? Can you clarify what is an 'acceptable limit' for RMSE values, mentioned in the supplement right before Figure S5?

Response: Thank you for this comment. We understand the reviewer is likely referring to **Fig. S5**, which evaluates simulated versus observed **water levels** at two key stations (rather than discharge). There is no universal "acceptable" RMSE threshold because it depends on the model objective, domain complexity, boundary/forcing uncertainty, and observation quality. Here, we simulate a large, hydraulically complex river-lake-floodplain system using high-quality forcing and boundary datasets, and the resulting performance is strong in that context. Across the evaluation years, the water-level RMSE is approximately **12%.**
Importantly, the variables most critical to this study–**the exchange flow between Tonle Sap Lake and the Mekong mainstream** and **the timing of reverse flow onset and cessation**–are reproduced with high fidelity (Fig. S6; Table S2).

Lines 279-282: A sentence should be added here to explain that the no-dam scenario data presented are outputs from the THREW model.

Response: Thank you for your suggestion. We have added a sentence, and the revised text now reads as follows (revised manuscript, line 351):

"Six rose diagrams (Fig. 2a-f) summarize the spatiotemporal evolution of discharge dynamics across eight mainstream stations from Chiang Saen to Kratie. The top row shows observed changes across three hydrological periods, while the bottom row compares measured conditions with a no-dam counterfactual for the post-dam era (2010-2024). All metrics are derived from the daily discharge series. The no-dam daily discharge series for 2010-2024 is taken from the THREW model simulations."

Lines 292-300: The RBI patterns described in the text do not reflect what is shown in Figure 2 panels b and e. In addition to the discrepancies between text and Figure 2, post-dam RBI (panel b) and measured RBI (panel e) should be identical, but this is not the case here.

Response. We agree that this is a valid point and appreciate the reviewer for bringing it to our attention. We have recalculated all panels and revised the corresponding text so that the figure and manuscript are now fully consistent. Please see the updated figure and the revised section below (revised manuscript, Section 3.2).

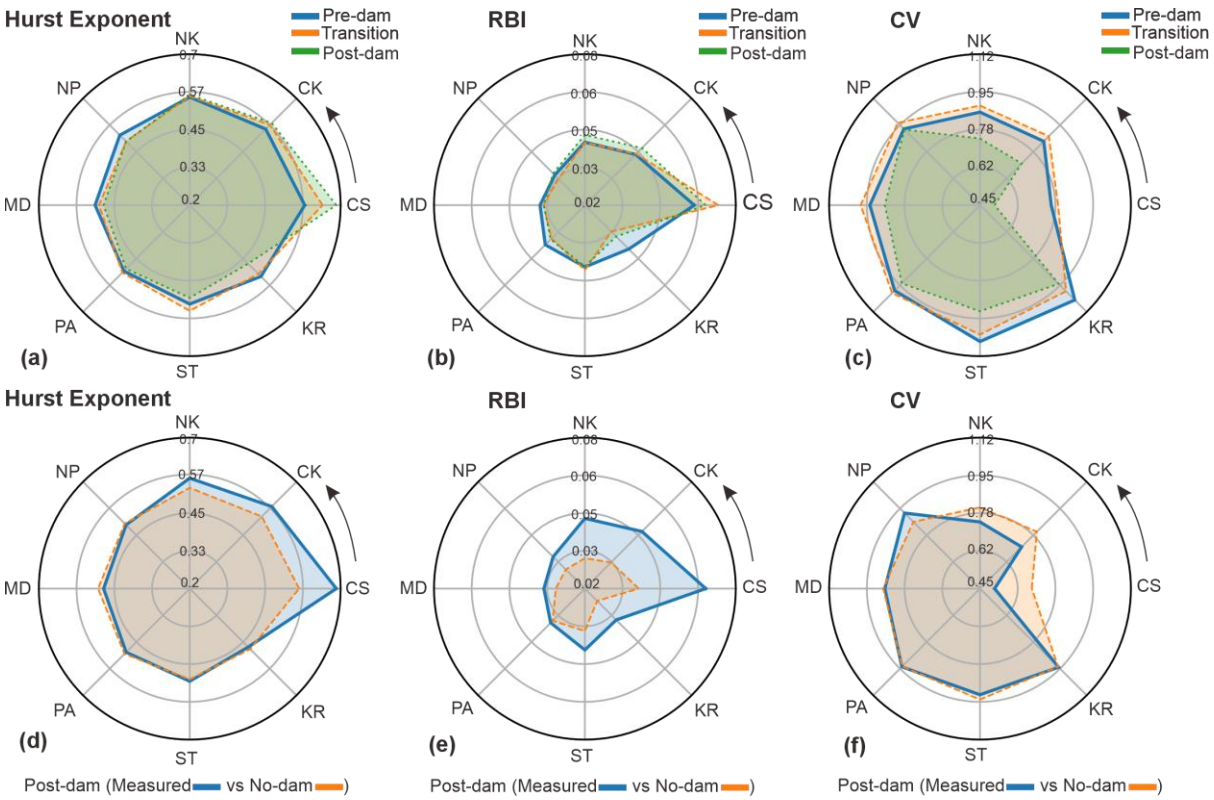
"Six rose diagrams (Fig. 2a-f) summarize the spatiotemporal evolution of discharge dynamics across eight mainstream stations from Chiang Saen to Kratie. The top row shows observed

changes across three hydrological periods, while the bottom row compares measured conditions with a no-dam counterfactual for the post-dam era (2010-2024). All metrics are derived from the daily discharge series. The no-dam daily discharge series for 2010-2024 is taken from the THREW model simulations.

Flow memory (Hurst exponent, H) captures long-range persistence in daily discharge variability (Fig. 2a). H is highest upstream and generally decreases downstream across all periods, but the upstream-downstream contrast strengthens in the post-dam era. For example, H increases at Chiang Saen from ~0.58 (pre-dam) to ~0.69 (post-dam), whereas Kratie decreases from ~0.53 to ~0.47. The post-dam measured–vs–no-dam comparison confirms that the increase in persistence is concentrated in the regulated upper reach: measured H exceeds the no-dam case at upstream stations (e.g., Chiang Saen: 0.69 vs 0.56), while differences are small and can reverse in the lower basin (e.g., Kratie: 0.47 vs 0.48) (Fig. 2d). This pattern is consistent with reservoir operations strengthening persistence upstream, while monsoon-driven runoff contributions from downstream tributaries and adjacent floodplains, which become increasingly important in the lower basin modulate (and may offset) that signal.

Daily flashiness (RBI) quantifies day-to-day discharge fluctuations (Fig. 2b). RBI is consistently largest at the upstream station (Chiang Saen) and decreases toward the mid-lower basin in all periods, with values on the order of ~0.03–0.07. Across periods, RBI increases modestly at the upstream stations (e.g., Chiang Saen: ~0.060 pre-dam to ~0.065 post-dam), but declines at downstream stations (e.g., Kratie: ~0.043 to ~0.036), indicating spatially heterogeneous changes in day-to-day variability (Fig. 2b). In the post-dam measured–vs–no-dam comparison, measured RBI is higher than the no-dam counterfactual at all stations, with the strongest relative increase upstream (e.g., Chiang Saen: 0.065 vs 0.039; Chiang Khan: 0.050 vs 0.033) (Fig. 2e). This suggests that, at the daily scale, regulation is associated with enhanced day-to-day fluctuations relative to the counterfactual hydrograph, while the magnitude of this effect weakens downstream.

Amplitude variability (coefficient of variation, CV) reflects the combined seasonal and interannual variability of daily discharge (Fig. 2c). CV is high in the pre-dam and transition periods and tends to increase downstream, but it declines substantially in the post-dam era at upstream sites (e.g., Chiang Saen: ~0.77 pre-dam to ~0.52 post-dam; Chiang Khan: ~0.85 to ~0.71), consistent with dampened wet-season peaks and enhanced dry-season flows under reservoir regulation. The post-dam measured–vs–no-dam comparison supports this interpretation in the upper reach (e.g., Chiang Saen: 0.52 vs 0.68; Chiang Khan: 0.71 vs 0.81; Nong Khai: 0.74 vs 0.81), whereas differences are small downstream (e.g., Mukdahan-Kratie) (Fig. 2f), consistent with attenuation of the regulation signal and increasing influence of tributary inflows and floodplain dynamics in the lower basin."



Lines 413-415: It is unclear what these lines refer to. Earlier it has been demonstrated (Lines 355-377) that the median value of the annual maximum discharge is reduced in the post-dam period by 9%. RBI flashiness is also reduced at Kratie in the post-dam period based on Figure 2. These results do not support the claim of intensification of the hydropeaks.

Response: Thank you for this helpful comment. We agree that the original wording in lines 413-415 (original submission) **was unclear and overly general**. Following the updates to Figures 2 and 3, and the reviewer's suggestion (reviewer 1) to move Figure 5 into the Results section, we have substantially revised the Discussion to improve clarity and specificity. Please refer to the revised manuscript, Section 4.

Lines 421-425: The argument here is constructed in a confusing way and it is not clear why cessation of the reversal of the Tonle Sap River requires high discharge values at Kratie.

Response: Thank you for highlighting this ambiguity. We agree the original wording could be misread as implying that high discharge causes cessation. In our analysis, the "cessation threshold" denotes the lag-adjusted Kratie discharge at the time reverse flow ends, i.e., when the Mekong-lake hydraulic gradient is no longer positive; it is therefore timing-dependent and influenced by lake storage. We clarified this in Sect. 3.5 and added a short explanation that **cessation now occurs earlier in the year (late September rather than early October), which can correspond to higher Kratie discharge because September is closer to the seasonal high-flow period.** The revised text now reads as follows (lines, 478 to 484)

"Figure 5b presents the lag-adjusted discharge thresholds at Kratie associated with the onset (rising limb) and cessation (recession limb) of reverse flow into the lake. In the pre-dam period (1976-1991), reverse flow typically initiated when discharge exceeded ~3,000 $m^3 s^{-1}$ and ceased when discharge declined to ~28,000 $m^3 s^{-1}$. In the post-dam period (2010-2024), the onset discharge increased by 130% to ~7,000 $m^3 s^{-1}$, while reverse flow ceased when discharges fell to ~34,000 $m^3 s^{-1}$ (with some years surpassing 40,000 $m^3 s^{-1}$). This higher cessation value is consistent with earlier termination (late September rather than early October; Fig. 5c), when mainstream discharge is typically higher than during October, and with onset-cessation hysteresis driven by seasonal lake storage."

Lines 427-428: The authors omit the study published by Quan et al., Nat Sustain 8, 1455–1466 (2025) which demonstrates the impacts of sand mining on the flow reversal of the Tonle Sap River.

Response: Thanks for your comment. At the time of our initial submission, the study by Quan et al. had not yet been published. We are aware of this important work and now cite it in several relevant sections of the revised manuscript.

Lines 435-436: The effect of channel deepening which has drastically changed the hydraulic head required to reverse the flow of the Tonle Sap River should be included here.

Response: Thank you for your suggestion. We agree that addressing this point strengthens the Discussion. We have revised the relevant part accordingly; the discussion related to this comment now appears in the revised manuscript (lines 536-544, Section 4.2), which read as follows:

Two mechanisms are likely acting together. First, changes in the shape and timing of the Mekong hydrograph–particularly weaker early wet-season rises and a more abrupt approach to peak flow–reduce the persistence of the hydraulic gradient required to initiate and sustain reversal. Second, local hydraulic and geomorphic changes in the confluence reach can modify conveyance and the head difference required for reversal (Quan et al., 2025). In particular, recent satellite-based estimates indicate that sand extraction from the Cambodian Mekong increased from ~24 Mt in 2016 to ~59 Mt in 2020, while natural sand supply in 2020 was only ~3.7 Mt, implying a large and persistent sediment deficit (Hackney et al., 2021). This deficit is associated with reach-scale bed incision (median ~−0.26 m yr^{-1} over 2013-2019) (Hackney et al., 2021) and intense local lowering near the confluence (net incision ~1.2 m a^{-1}) (Hackney et al., 2025), providing a physically consistent pathway for threshold shifts via changes in cross-sectional geometry and stage-discharge relations.

Lines 439-444: The argument here is speculative. The figure shows very well the modulation of Mekong's water flux in the post-dam era and the shortening of the duration of the TSR reversal but do not show the drivers for these changes.

Response: We agree with the reviewer. The previous wording overstated attribution of the patterns in Fig. 5 to specific drivers. Fig. 5 is intended to **describe** changes in hydrograph shape, lag-adjusted onset/cessation thresholds, and reverse flow timing; it does not isolate causal

contributions of dam regulation, climate variability, or sand mining. We therefore revise the text to remove causal language ("drivers are implicated", "primarily driven", "shaped by…") and replaced it with wording that (i) reports the observed shifts and (ii) clarifies that mechanistic attribution is discussed separately and remains beyond the scope of Fig. 5. Please refer to the revised manuscript lines 468 to 489.

Lines 484-485 The statement here is misguided. The reduction of Mekong water discharge cannot affect the threshold required to initiate flow reversal in the Tonle Sap River. This threshold is governed by channel geometry. The magnitude of the hydropeak affects when and for how long this threshold is exceeded and reversal occurs.

Response: Thanks for this nice comment. Yes, we agree with the reviewer. The revised text now reads as follows (589 to 599)

"These mainstream alterations propagate into the Tonle Sap system, where the reverse flow period is shortened by approximately 24 days in the post-dam period compared to the pre-dam baseline as a compound outcome of altered flow regime and local geomorphic change. The hydraulic trigger for reversal at the Mekong-Tonle Sap confluence is the local stage/head condition required to reverse the along-channel gradient, which is governed primarily by channel geometry and confluence hydraulics. Within this framework, sand mining-driven riverbed incision reduces confluence stage for a given discharge, thereby increasing the lag-adjusted Kratie discharge required to attain the confluence stage associated with reversal. Consistent with this mechanism, the median lag-adjusted Kratie discharge at reverse flow initiation increased from ~3,000 $m^3 s^{-1}$ (pre-dam) to ~7,000 $m^3 s^{-1}$ (post-dam), an increase of >130%. Superimposed on this shifted hydraulic setting, dam regulation and climate change reshape the seasonal hydrograph–dampening early wet season rises and altering flow timing and persistence–thereby reducing how frequently and how long the reversal-favourable confluence stage/head condition is exceeded. Together, these interacting drivers shorten and retime the reverse-flow season."

Figure 1: The labels of the panels need attention as two panels are labelled as '(a)'. Then later in the main text (line 192) 'Figure 1 panel c' is mentioned. Also, you should provide the sources for the data presented (for example on dam locations).

Response: The two panels labelled "a" in Fig. 1 were intended to indicate that they are directly linked: the larger panel provides a zoomed-in version with additional detail of the smaller panel. We acknowledge the lettering inconsistency (e.g., the use of "c"). We created a new figure based on the reviewer's previous comment. Please refer to Figure 1 of the revised manuscript or previous comments. Thanks.

Figure 2: I am not convinced that the use of rose diagrams is appropriate here. For example, a connection between the furthest upstream station (Chiang Saen) and most downstream (Kratie) is implied. I suggest using line plots with stations placed in order along the x-axis, possibly with the in-between distances scaled according to the station km point along the Mekong mainstem. Also, please explain the abbreviations used for the names of the stations in the figure caption.

Response: Thank you for the suggestion. We agree that a rose diagram could be misread as implying circular connectivity between the most upstream and most downstream stations. Our intention, however, is not to depict geographic connectivity, but to provide a compact comparative display of multi-station changes across hydrological periods and metrics, where the circular layout improves readability relative to multiple line panels with many overlapping series.

To avoid misinterpretation, we have revised Figure 2 by (i) explicitly ordering stations counterclockwise from upstream to downstream and (ii) adding a clear **"Upstream → Downstream"** directional annotation. We also expanded the figure caption to define all station abbreviations and to **clarify that the curved arrow indicates the station sequence from upstream to downstream within each panel. The revise Figure 1 caption now reads as follows (lines 380-388):**

"Figure 2. Spatial patterns of streamflow memory, flashiness, and variability along the Mekong mainstream under observed and no-dam conditions. Six rose diagrams summarize hydrological dynamics at eight mainstream stations from Chiang Saen to Kratie. The top row (a-c) compares three hydrological periods–pre-dam (1976-1991), transition (1992-2009), and post-dam (2010-2024)–for (a) the Hurst exponent (H), (b) the Richards-Baker flashiness index (RBI), and (c) the coefficient of variation (CV). The bottom row (d-f) compares post-dam conditions under observed (measured) and a no-dam counterfactual simulated with the THREW hydrological model. Curved arrow indicates the station sequence from upstream to downstream within each panel. Station abbreviations are CS, CK, NK, NP, MD, PA, ST, and KR for Chiang Saen, Chiang Khan, Nong Khai, Nakhon Phanom, Mukdahan, Pakse, Stung Treng, and Kratie, respectively."

Figure 3: Presenting data as monthly averages using all years (right panels) and annual averages (left panes) suppresses information that would be helpful to understand spatio-temporal changes of the metrics. For example, the monthly data show an uptick for Nakhon Phanom in amplitude and flashiness for January, is this primarily driven by the huge spike in 2022?

Response: Thank you for this helpful point. We agree that pooling all years into monthly means (right panels of Fig. 3) can mask interannual variability and, in some cases, allow an anomalous year to disproportionately influence the monthly climatology. Because sub-daily water level records are available only for 2018-2024 in the original submission and the monthly metrics were summarized as means, we revised the presentation to make year-to-year variability explicit. In the revised version, we obtained additional MRC data and extended the sub-daily record to include 2025. We then re-analyzed the sub-daily metrics and now report monthly values by year.

In the main text, we present results for three representative stations: Chiang Saen (CS), as the closest station to the Chinese cascade dams; Mukdahan (MD), representing the middle reach; and Kratie (KR), the station most proximal to the Tonle Sap system. Results for the remaining stations are provided in the Supplementary Information (Figure S7). Accordingly, Section 3.3 has been fully revised, and now reads as follows:

"Figure 3 illustrates sub-daily water level dynamics at three representative mainstream stations–Chiang Saen (CS; Fig. 3a-c), Mukdahan (MD; Fig. 3d-f), and Kratie (KR; Fig. 3g-

i)–using three complementary metrics: (i) amplitude, defined as the intraday water level range (daily max-min; m), (ii) flashiness (RBI) computed from sub-daily water level changes, and (iii) peak count, defined as the mean number of hourly water-level rises ≥ 5 cm h^{-1} per day. The 5 cm h^{-1} threshold follows MRC guidance as a rate-of-change level above which ecological impacts may increase (MRC, 2020).

Amplitude exhibits a consistent wet-season intensification across the three stations, but with station-specific magnitude and timing (Fig. 3a, d, g). At CS, amplitudes increase markedly during the wet season (typically June–September), with notable high-variability months including July 2021 (~0.48 m) and August–September 2024 (~0.40–0.46 m), while many dry-season months remain comparatively muted. At MD, amplitudes are generally lower and more moderate, but still strengthen during wet-season months (commonly July–September), reaching ~0.2–0.3 m in several years. At KR, the wet-season signal is more pronounced and can extend into late wet season, culminating in a strong event in September 2019 (~0.77 m). The corresponding matrices for the remaining stations (CK, NK, NP, PA, ST) show that larger amplitudes can occur at mid-reach stations in particular years/months (Supplementary Fig. S6), reinforcing that sub-daily variability is spatially heterogeneous and episodic.

Flashiness (RBI) broadly tracks the occurrence of rapid intraday changes but highlights the intermittency of short-lived fluctuation episodes (Fig. 3b,e,h). RBI at CS is generally low but displays distinct episodic enhancements, including a prominent increase in February 2022 (~0.004) and elevated wet-season values during months of higher amplitude (e.g., July 2021). At MD, RBI remains low for many months but includes isolated months with higher values (e.g., late 2019 and early 2021), indicating that rapid fluctuations can emerge intermittently even when typical conditions are relatively smooth. At KR, RBI is usually low but increases during months with stronger wet-season dynamics, including September 2019 (~0.0017) and June 2020 (~0.0017), consistent with periods of intensified intraday variability. Supplementary Fig. S6 indicates that some mid-mainstream stations can reach substantially higher RBI in specific wet-season months, underscoring the episodic nature of flashiness along the reach.

The peak count metric isolates where rapid hourly rises are frequent and shows that exceedances of the 5 cm h^{-1} threshold are seasonally concentrated and event-driven rather than pervasive (Fig. 3c, f, i). At CS, peak counts are zero in many months but rise sharply during certain wet-season months, including July 2021 (~2.0 events day^{-1}) and August–September 2024 (~1.3-1.4 events day^{-1}). At MD, exceedances are rarer overall and typically confined to isolated wet-season months (e.g., July 2018 and August 2020), indicating fewer frequent rapid-rise events than at CS and KR. At KR, exceedances can be both larger and more frequent in the wet season, with a major episode in September 2019 (~4.4 events day^{-1}) and elevated activity in June 2020 (~2.6 events day^{-1}). Across the full station set (Supplementary Fig. S6), the most frequent exceedances occur at selected mid-reach stations during particular wet season months, highlighting strong spatial clustering of rapid water-level rises."

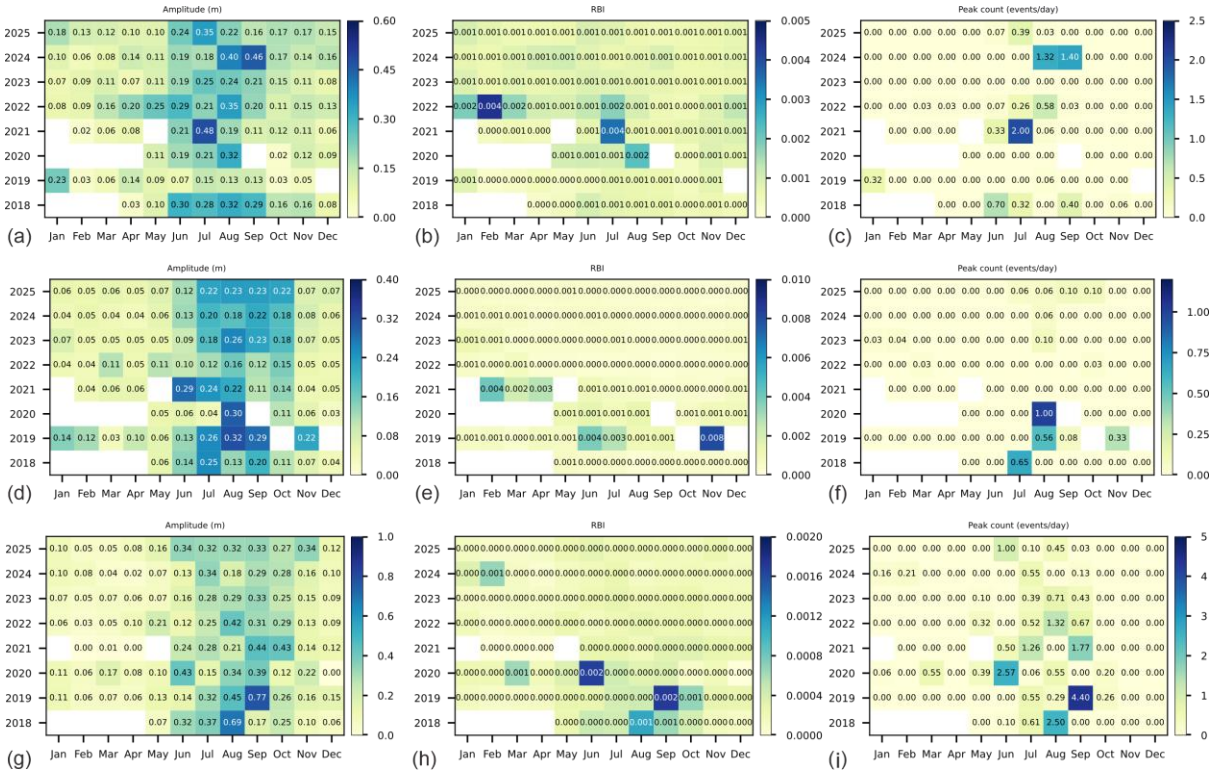


Figure 3. Sub-daily water level variability at three representative Mekong mainstream stations (2018-2025). Sub-daily dynamics are quantified from 15-min water level observations using three complementary metrics: intraday amplitude (daily max-min water level, m), flashiness (Richards-Baker Index, RBI, computed from sub-daily water-level changes), and peak count (mean number of hourly water-level rises ≥ 5 cm h^{-1} per day). Panels (a-c) show Chiang Saen (CS); panels (d-f) show Mukdahan (MD); and panels (g-i) show Kratie (KR). Each panel displays monthly values by year; numbers denote the metric value for that station–month. Blank cells indicate months without available 15-min water level records. Results for the remaining mainstream stations (Chiang Khan, Nong Khai, Nakhon Phanom, Pakse, and Stung Treng) are shown in Supplement, Fig. S7.

Also on Figure 3: Extreme values in 2018 for Chiang Khan (amplitude and flashiness) and Pakse (all metrics) and 2022 Nakhon Phanom (all metrics) should be discussed in the text.

Response. Thanks for your comment. Please refer to the revised section 3.3 and previous comment.

Technical corrections:

Line10: add 'the' before Tonle Sap Lake

Response: We have revised the sentence as follows (lines, 10-11).

"This study provides an integrated, multi-scale assessment of flow regime alteration across the Mekong mainstream and its coupling with the Tonle Sap Lake for three periods"

Line 99 and throughout the manuscript MCM is not a universal abbreviation. I suggest to use M m3

Response: We agree. To avoid ambiguity, we replaced "MCM" with using "$\times 10^6$ m^3" (million cubic metres) and updated the first occurrence accordingly. For example, see revised manuscript, lines 118 to 119, which reads as follows:

"Eleven large dams are now located on the upper Mekong (Lancang) in China (Fig. 1a), with a collective storage capacity exceeding 43,000 million m^3 (Mm^3). Among them, the Xiaowan (14,645 Mm^3, completed in 2010) and Nuozhadu (21,749 Mm^3, completed in 2014) reservoirs dominate in both scale and operational influence (Zhang et al., 2023)."

Line 126: replace 'part (a)' with 'panel (a)'

Response: Thank you for your suggestion. We now refer explicitly to Figure 1a and Figure 1b in the revised manuscript. The revised text (lines 146-152) reads as follows:

……, ranging from Chiang Saen in northern Thailand (representing upper-basin inflow conditions) to Kratie in Cambodia (located upstream of the Tonle Sap confluence) (Fig. 1a). ……. within the Tonle Sap Lake (Fig. 1b). These stations were used to ……..

Line 170: delete 'of the Sea'

Response: Thanks for suggestion. We delete "of the Sea". The revised sentence now reads as follows (line 247)

"The model domain spans from the Kratie gauging station in Cambodia to approximately 80 km offshore, encompassing the Tonle Sap Lake and River, the Cambodian floodplain, and the Vietnamese delta (Fig. 1b)."

Line 180: the hydrological model is described in Sect. 2.5.3

Response: Thanks for your comment. Following the reviewer's suggestion (reviewer 1), we now present the hydrological model first as Section 2.5.1. We have revised the text accordingly to ensure consistency between the section numbering and the in-text references.

Line 408: the correct figure is 5a (not 6a)

Response. We apologize for the oversight. We changed "6a" to "5a" as suggested.

Line 421: Replace 'Panel 5b' with 'Figure 5b'

Response. We apologize for the oversight. We replaced 'Panel 5b' with 'Figure 5b' as suggested.

Throughout the manuscript there is an overuse of em dashes (–). In most cases these should be replaced with commas or with hyphens when used for ranges (e.g. 1976-1991, not 1976–1991) or connections (e.g. Tonle Sap-Mekong , not Tonle Sap–Mekong).

Response: We agree that dashes were overused. We revised the manuscript to appropriately use em dashes (–). Thank you.