We wish to thank the reviewer for the constructive comments and suggestions. We have carefully revised the manuscript according to the reviewers' comments. Detailed response to all comments is given below (the reviewer's comments are shown in black, while authors' responses are marked in blue. Text from the manuscript is italicized, and the proposed revision are highlighted in yellow).

Reviewers' comments

Reviewer #3: In this contribution, the authors evaluate the overlooked role of riverine suspended sediments in driving hypoxia in an estuary, using model experiments. The study looks in particular at the case of the Pearl River Estuary in China. The authors use controlled model experiments in a 3D model with a biogeochemistry module to evaluate the role of three drivers of hypoxia: dissolved oxygen (DO) concentrations, nutrient levels and suspended sediment concentrations (SSC) in river export. They find that SSC plays a significant role, and that the sensitivity of hypoxia to each of these factors varies with distance to the river mouth. The authors finish by discussing how this has important implications for hypoxia mitigation strategies in estuaries, as overlooking SSC can lead to an overestimation of the role of nutrient loading.

This manuscript represents a valuable contribution, showing the importance of a previously overlooked driver of hypoxia in coastal areas. The figures support the findings very well. This manuscript would be ready for publication after correcting some deficiencies in the description of the data and of the model forcing. The presentation of the results could also benefit from more quantitative evaluations and from a better synthesis.

Response: Many thanks for the positive feedback. Please find our detailed response below.

General comments

1. Even if the goal of this study is first and foremost to present the results of modeling experiments, the authors present some results or figures based on data (Fig. 1c-f. Fig. 2). Hence, a method section describing the data and how it was processed is currently missing:

(a) The data used should be presented. In Table S1, some datasets refer to "This study", but the data is not described.

Response: We agree with the reviewer's comment. The phrase "this study" is not accurate. We will revise the relevant descriptions in Table S1 as follows.

Table S1. Data source of long-term water quality changes in the Pearl River Estuary.

Data	*Year*	*Source*
Bottom DO	1985-2013	Hu et al., 2021 (DOI: 10.5194/bg-18-5247-2021)
Bottom DO	2014	Su et al., 2017 (DOI: 10.5194/bg-14-4085-2017)
Bottom DO	2015&2017	Li et al., 2021 (DOI: 10.1029/2020JC016700)
Bottom DO	1990-2017	Environmental Protection Department of Hong Kong (www.epd.gov.hk)

Riverine DIN, DIP, DO	1990-2017	Hu et al., 2021 (DOI: 10.5194/bg-18-5247-2021); Ministry of Ecology and Environment of the People's Republic of China (https://www.mee.gov.cn/)
Riverine SSC	1990-2017	China River Sediment Bulletin (http://www.mwr.gov.cn/sj/tjgb/zghlnsgb/)

Note: DO (dissolved oxygen); dissolved inorganic nitrogen (DIN); dissolved inorganic phosphorus (DIP); suspended sediment concentration (SSC).

(b) How are the time series in Fig. 1d-f obtained? Is it an average? Is it at a specific depth? Also, error bars are missing on Fig. 1c-f

Response: The observed nutrient and dissolved oxygen concentrations (June-August) were obtained from sampling points near river outlets (the Humen station shown in Fig. 1a), compiled from published studies and public databases (see the revised Table S1 for details). These measurements represent surface water conditions, collected within the upper 2 m of the water column. Error bars were not included due to the limited sampling data size (~2-4 sampling points per year).

We will revise the caption of Fig 1 as follows:

"*Fig. 1. (a) Study area of the PRE and sampling sites during 1985-2017; (b) five subregions and a transect along the coastal transition zone used for analysis; (c) annual loads of suspended sediments (SS) from the Pearl River; (d-f) the surface-layer (within the upper 2 m of water column) summertime concentrations of nutrients (DIN, DIP) and dissolved oxygen (DO) in the river outlets of the PRE.*"

(c) How are bottom waters defined in producing Fig. 2? Is this the concentration at a specific depth or vertically integrated over a specific range? What method is used to estimate the area, in particular in years in which the sampling is less extensive?

Response: The dissolved oxygen (DO) data shown in Fig.2 are compiled from published studies (see the revised Table S1 for detailed sources), with bottom-water DO concentrations derived from sampling points 1-2 m above sediments. We will revise the caption of Fig.2:

"*Fig. 2. (a) Interannual variations of low-oxygen area (HA4, DO < 4 mg/L) and hypoxic area (HA3, DO < 3 mg/L) in the bottom waters (~1-2 m above sediments) of the PRE during summer estimated from the cruise observations (note that the grey patches represent the lack of data); spatial distributions of summer-averaged DO concentrations during (b) 1991-1996 and (c) 2013-2017.*"

We estimate the hypoxic (DO ≤ 3 mg/L) and low-oxygen (DO ≤ 4 mg/L) areas through the following MATLAB processing steps: 1) a 0.01° × 0.01° latitude-longitude grid was established for the Pearl River Estuary, onto which all annual dissolved oxygen data were interpolated; 2) grid cells with dissolved oxygen concentrations meeting the threshold criteria (≤ 3 mg/L or ≤ 4 mg/L) were identified, and their cumulative areas were calculate to determine total hypoxic or low-oxygen areas.

For years with sparse sampling (e.g., 1989 with only 2 sampling sites; 1993 with only 4 sampling sites), we excluded the area calculations due to insufficient spatial coverage for reliable interpolation. These data were retained solely for visualizing the temporal trends of bottom-water dissolved oxygen concentrations (Fig. 2b, c).

(d) A description of how the nutrient limitation factor and the euphotic depth are calculated is missing. From my general understanding, nutrient limitation evaluates which nutrient is limiting, so a few words on how this is linked with whether productivity is limited by nutrients or light would be useful.

Response: The calculation equation of nutrient limitation factor is shown in the Line 186-195 of the manuscript, in which a value closer to 1 indicates a weaker limitation. We will emphasize it in Line 186:

Line 186-193: "*The nutrient limitation factor* $(G_N(N))$ *is parameterized as:*

$$G_N(N) = Min\left(\frac{DIN}{K_{mN} + DIN}, \frac{DIP}{K_{mP} + DIP}, \frac{Si}{K_{mSi} + Si}\right)$$

where DIN, DIP, *and* Si *represent the concentration (mg* L^{-1}*) of dissolve inorganic nitrogen (including* NO_3^- *and* NH_4^+*), dissolve inorganic phosphorus (PO43-), and dissolve inorganic silicon (*SiO_3^{2-}*), respectively;* K_{mN}, K_{mP}, *and* K_{mSi} *represent the half-saturation constants (mg* L^{-1}*) for* DIN, DIP, *and* Si*, respectively. It should be noted that a higher nutrient limitation factor* $G_N(N)$ *indicates a weaker nutrient limitation effect on phytoplankton growth.*"

The eutrophic depth is defined as the water depth reached by 1% of the surface light intensity, in which a larger eutrophic depth indicates a better light condition. As suggested, we will add the calculation equation of eutrophic depth after the Line 210:

"*To estimate the spatial characteristics of light conditions, we also calculated the eutrophic depth* $(H_E$*, Equation 7) in the PRE, which is defined as the water depth reached by 1% of the surface light intensity* (I_{surf})*.*

$$I_{surf} * e^{-k_e * H_E} = I_{surf} * 1\% \quad (7)$$

where H_E *represents the eutrophic depth (m).*"

2. The authors mention that this model has been used many times previously. Hence, I would suggest that this contribution does not need a full description of the model in Section 2.2.1, which could be shortened, replacing it with a short description of the model's specificity. Instead, what was not clear to me was the model forcing. I suggest improving the description at L244-246, providing more details about what inputs are required by the model, what the data source is used, and how the data is processed. Here are some specific points:

(a) From the text it seems like there is one river input to the model. Is this the case, since this is a 3D model and since from Fig. 1a it looks like there are multiple outlets into the region?

Response: We thank the reviewer for their question regarding the river inputs in the model. As shown in Figure 1a, the PRE receives freshwater and nutrient inputs from eight major river outlets, all of which are represented in our model.

For the water quality module, we apply uniform concentrations of transported substances (e.g., nutrients, sediments) across all eight outlets. This simplification assumes relatively homogeneous upstream river conditions, enabling greater focus on the estuarine spatiotemporal dynamics. However, the 1D model component calculates distinct flow rates for each outlet, preserving the hydrodynamic variability arising from differential freshwater inputs.

We will add these relevant descriptions in Text S1 of the Supplementary Materials.

(b) What data is used for the physical conditions?

Response: The physical forcing used in our model include rivers, tides, and atmospheric conditions. We will improve the relevant model description in the revision:

In Line 244: "*Each case was run from 1 January to 31 August, driven by climatological physical conditions (freshwater discharges and wind speeds, detailed in Text S1 of the Supplement) averaged over 1990-2017 and by mean observed values of riverine water quality components in the corresponding period.*"

In the Text S1 of the Supplement:

"*The Gaoyao, Shijiao, and Boluo sites were forced by real-time river discharge data, while the Laoyagang and Shizui sites were forced by real-time water level data, which were provided from the Pearl River Water Resources Commission of the Ministry of Water Resources (https://www.pearlwater.gov.cn/sssq/). The riverine salinity at the upstream boundaries was set to zero. The initial conditions of water levels and salinity in the 1D model domain were set to zero.*" …

"*Along the three open boundaries at the east, west, and the south, the tide forcing in the form of water levels was obtained from Oregon State University Tidal Data Inv ersion Software (OTIS). Observed temperature and salinity profiles were spatial-unifo rmly applied at the three open boundaries (Hu and Li, 2009). The atmospheric conditi ons (e.g., wind speed, wind direction, and solar radiation) were interpolated onto the model grid, forced by the six-hourly reanalysis product of ERA-Interim (http://www.ec mwf.int/en/research/climate-reanalysis/era-interim). The initial temperature and salini ty conditions were spatial-uniformly set to 20 °C and 34.5 PSU, respectively.*"

(c) Are the physical conditions inputs (winds, river output, stratification) the same in all experiments or do they vary?

Response: In this study, the physical condition inputs (e.g., wind speed, river discharge, and stratification) were kept consistent across all experiments. As we described in Line 244:

"*Each case was run from 1 January to 31 August, driven by climatological physical conditions (freshwater discharges and wind speeds, detailed in Text S1 of the Supplement) averaged over 1990-2017 and by mean observed values of riverine water quality components in the corresponding period.*"

This design aims to reduce the complexity of the model analysis and ensure that the results focus on the key issues of this study, particularly the impacts of nutrient inputs and light attenuation on hypoxia dynamics in the PRE.

By maintaining consistent physical conditions, we can eliminate interference from other confounding factors, thereby more clearly analyzing the effects of the main variables (e.g., nutrient concentrations and light conditions). This simplification allows us to more definitively attribute changes in hypoxia patterns to the specific driving factors under investigation.

We would also like to emphasize that our investigations are grounded in a process-oriented modeling approach. This methodology does not aim to replicate observations on a point-by-point basis but rather seeks to explore the fundamental processes governing system behavior. Such exploration is an essential step toward developing diagnostic and predictive models (Franks, 2018), which may not be attainable through a direct-modeling approach.

3. The objective of the mode experiments is to evaluate the sensitivity of the system's bottom DO to different factors. Hence, I suggest to significantly reduce the description of the oxygen and hypoxia extent results of the model in section 3.2.1 to talk more and more quickly about the processes (3.2.3).

Response: We appreciate reviewer's suggestions. Following the suggestion, we will streamline Section 3.2.1 as follows:

Line351: "*Our model revealed distinct temporal shifts in summertime DO patterns and hypoxia distribution (Fig. 5). 1990s surface waters generally maintained DO >6 mg/L, increasing toward shelf regions (Fig. 5a). By the 2010s, surface DO increased 0.2-0.3 mg/L (Fig. 5b-c), with an oxygen-enriched zone in the lower PRE correlating with high Chl a (Fig. 3k), though new low-oxygen zones (DO <4 mg/L) emerged near river outlets due to reduced Pearl River DO influx.*

Bottom water simulations captured the hypoxia expansion from localized 1990s events (Fig. 2b-c) to widespread 2010s occurrences (Fig. 5d-e). Initial hypoxia clustered along the western PRE (Modaomen sub-estuary; Fig. 5d), with simulated HA4 (1179.7 km²) and HA3 (211.3 km²) (Table 3) matching observations (802±437 km² and 131±84 km²; 1994-1999 summers; Fig. 2a). By the 2010s, hypoxia intensified throughout Lingdingyang Bay and Hong Kong waters, with bottom DO declining to 2.8-4.1 mg/L (Table 2). Simulated HA4 expanded 1.5-fold to 2925.5 km² (Table 3), consistent with observed 2715±1068 km² (2013-2017; Fig. 2a). HA3 doubled to 617.2 km² by the 2020s, comparable to observed 901±591 km² (2013-2017).

In addition, our model accurately replicated the two observed hypoxic centers along the coastal transition zone (Modaomen sub-estuary and Hong Kong waters; Fig. 2b-c), revealing distinct spatiotemporal deoxygenation patterns (Fig. 5g-o). During the 1990s, both centers exhibited limited low-oxygen zones, with Hong Kong waters showing <1 m thick DO <4 mg/L layers (Fig. 5g). Low-oxygen (HF4) and hypoxic (HF3) conditions persisted 18-76 days (20.5%-84.5% frequency) and 4-23 days (4.8%-25.2%) respectively during summer months (Fig. 5j,m; Table 2).

By the 2010s, hypoxic thickness increased substantially to ~1.5 m at Modaomen and ~5 m (~4 m thicker than 1990s) at Hong Kong waters (Fig. 5h). Event durations prolonged to 55-89 days (61.0%-99.1% HF4) and 19-51 days (21.4%-56.5% HF3) respectively (Fig. 5k, n; Table 2), demonstrating intensified and prolonged hypoxia."

4. The analysis of the model results should be improved by making it more quantitative and by putting forward some of the important findings.

(a) First, at L468-474, I suggest to make it more clear that the effects of nutrient loading and SSC are not linearly additive, and to discuss why. The authors could also use Fig. 7 to show how the two effects sometimes add up linearly in some regions and not in others. In some regions the effect is even amplified (sum of the two experiments > two individual experiments, as mention at L524), while in others the sum is lower (currently not mentioned/discussed). This should be discussed.

Response: We appreciate reviewer's insightful comments. We will add the following discussion in Section 4.1:

"As shown in Figure 7 and Table 3, the combined effect of reducing SSC and increasing nutrient inputs (DO-restore case) led to a significant expansion of low-oxygen conditions, with hypoxic areas (HA4) and low-oxygen areas (HA3) reaching 2409.7 km² and 617.2 km², respectively. This combined effect exceeded the sum of changes induced by individual river inputs, highlighting the non-linear interaction between SSC and nutrient loading. In regions such as Outer Lingdingyang and Hong Kong, the combined effect was amplified, while in regions such as Inner and Middle Lingdingyang, the combined effect was less than the sum of individual effects. The growth of phytoplankton is not a linear process in response to various influencing factors; instead, these factors interact cumulatively. Therefore, when different factors are combined, their combined effect can exceed the impact of individual factors acting alone."

(b) Second, the authors offer a quantification for the role of DO river input (44%), but not for the other factors. Even if this quantification varies spatially and the effect is not linearly additive, I suggest to provide some sort of quantitative assessment. This would help put forward the main result of this manuscript, which is that SSC plays an important role in driving hypoxia.

Response: As described in the text, we quantified the relative contributions of each factor to the low-oxygen and hypoxic area changes, with results summarized in Table 3. The 44% contribution from riverine DO input was obtained through comparison between the DO-restore case and the baseline 2010s case, and thus it is not reflected in Table 3. The calculation methods for these scenarios are as follows:

Equation 1 The calculation in Table 3 is:（$HA_x – HA_{1990s}$）/ HA_{1990s} , where x represents each case.

Equation 2 The 44% contribution of DO input is calculated as: (HA_{2010s} - $HA_{DOrestore}$) / HA_{1990s}.

We will add Equation 1 to Table 3 and included Equation 2 in the section discussing river DO input.

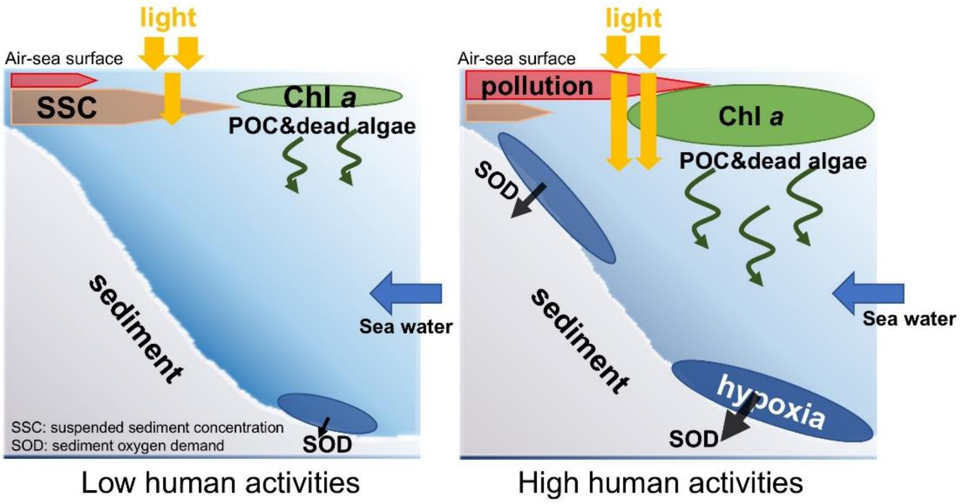
Specific comments:

Make sure to use a high enough resolution when extracting the figures.

Response: We will check all figures and updated them accordingly.

On the graphical abstract, we get the impression that sunlight is stronger under human activity. I suggest modifying to make it more clear that it is the light **penetration** that is stronger.

Response: We thank the reviewer for raising this important point. We will revise the graphical abstract to make light penetration clearer:



Abstract Figure. Comparative schematics of oxygen dynamics under low human influence (left) and high human influence (right) conditions. Note that pollution denotes inputs of DIN, DIP and low-oxygen water from anthropogenic discharge.

L79: I suggest specifying how human activity can reduce suspended sediment loads (what they say at L136). Also, human activity can sometimes act in the other direction and increase suspended sediment load (for instance under land change use that contributes to erosion, for during deforestation). The authors should acknowledge this possible scenario, perhaps discussing it in the discussion in the light of their findings (how this would reduce hypoxia).

Response: We thank the reviewer for raising this important point. Indeed, human activities such as land-use changes (e.g., deforestation or urbanization) may increase the load of suspended sediments in estuaries by exacerbating soil erosion and sediment transport. This scenario is an important consideration, as the increase in suspended sediments may reduce hypoxia by limiting light availability and suppressing phytoplankton growth, thereby decreasing organic matter production and subsequent oxygen consumption.

We will add the following description at Line 76:

"*Human activities, such as dam construction (Bussi et al., 2021) and soil-water conservation measures (Yang et al., 2024), can significantly reduce suspended sediment in estuaries.*

We will also add the following description between L568-L569 in the discussion section:

"*While our study highlights the impacts of reduced suspended sediments, human activities may conversely increase sediment loads in estuaries. For example, land-use* *changes such as deforestation (Kasai et al., 2005) or industrialization (Syvitski and Kettner, 2011) may exacerbate soil erosion and sediment transport, leading to higher suspended sediment concentrations in the water. In such cases, light attenuation due to increased turbidity may suppress phytoplankton growth and reduce primary production, thereby mitigating hypoxia."*

When we read section 2.2.2 on model validation, it gives the impression that the authors do not perform model validation in their specific setting. However, they do so in the results section, for instance comparing hypoxic areas at L365. I suggest to move this to the model validation section, and perhaps add a comparison of DO concentrations.

Response: We thank the reviewer for their suggestions. We will move the description in Line 365 to model validation section:

"*Our model demonstrated strong validation performance by accurately capturing the observed temporal expansion of hypoxia, transitioning from localized bottom hypoxia in the 1990s (Fig. 2b-c) to widespread occurrences in the 2010s (Fig. 5d-e). Initial validation against 1994-1999 summer observations showed close agreement, with simulated low-oxygen (HA4=1179.7 km²) and hypoxic (HA3=211.3 km²) areas matching observational estimates (802±437 km² and 131±84 km²; Fig. 2a, Table 3). For the 2013-2017 period, the model successfully replicated hypoxia intensification, as evidenced by HA4 expansion to 2925.5 km² aligning with observed 2715±1068 km². Projections to the 2020s indicated HA3 doubling to 617.2 km², remaining within observational uncertainty ranges (901±591 km²; 2013-2017 data), confirming the model's robustness in simulating both historical patterns and emerging hypoxia dynamics."*

Additionally, we will modify Line 358-374 by remove the information of validation:

"The model simulations revealed significant spatiotemporal evolution of bottom hypoxia in the PRE, transitioning from localized occurrences in the 1990s to estuary-wide expansion by the 2010s. During the 1990s, hypoxia predominantly developed along the western PRE (Modaomen sub-estuary; Fig. 5d), with simulated low-oxygen (HA4: 1179.7 km²) and hypoxic (HA3: 211.3 km²) zones concentrated in this region (Table 3). By the 2010s, hypoxia intensified markedly throughout Lingdingyang Bay and Hong Kong waters (Fig. 5e-f), accompanied by a 1.5-fold HA4 expansion to 2925.5 km² and a doubling of HA3 to 617.2 km² by the 2020s (Table 3). This spatial progression correlated with declining bottom DO levels, averaging 2.8-4.1 mg/L across subregions (Table 2), indicating system-wide deoxygenation acceleration."

In the introduction, the authors should cite more international studies discussing the processes behind deoxygenation, for instance (but not restricted to) Fennel & Testa 2019 (10.1146/annurev-marine-010318-095138); Rabalais et al. (2010), Dynamics and distribution of natural and human-caused hypoxia; Chan et al. 2019 (https://www.jstor.org/stable/26760084).

Response: We appreciate reviewer's suggestion. We will cite some relevant international studies in the introduction:

"Plenty of studies were conducted to reveal the mechanism of hypoxia formation and evolution in coastal regions. It has been widely recognized that coastal deoxygenation is largely attributed to the eutrophication-driven production of organic matters (Su et al., 2017; Howarth et al., 2011), which sink to the subsurface waters and bottom sediments, leading to intense oxygen depletion (Wang et al., 2014; Hagy et al., 2005). This would induce hypoxia when the density stratification restricts DO replenishment from the surface waters (Wang et al., 2018; Murphy et al., 2011). One important reason underlying eutrophication and hypoxia is the excessive nutrients that are discharged into the water column and stimulate phytoplankton blooms (Cullen, 2015; Cormier et al., 2023; Fennel and Testa, 2019). In addition, ..."

Fig. 1: The colorbar title on Fig. 1a says "Depth (m) relative to Pearl River Datumn", what is that reference point?

Response: This is because the topographic file for this figure is calculated based on the Pearl River Datum. To avoid the confusion, we will delete this reference point.

On Fig. 1, I suggest adding the main circulation features on the shelf on the map, and use it to discuss why SSC and nutrient loading impacts DO differently in different regions.

Response: We appreciate reviewer's suggestion. We will summarize the surface flow field processes in the study area, as shown in Figure 1b.

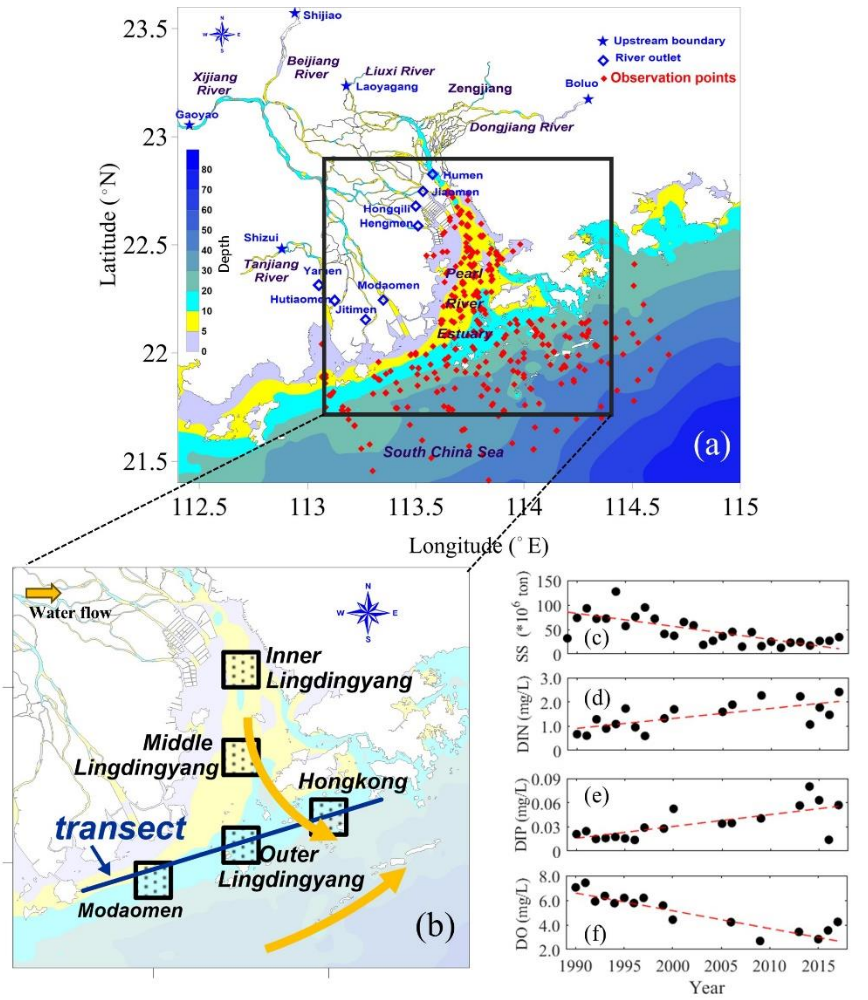


Fig. 1. (a) Study area of the PRE and sampling sites during 1985-2017; (b) five subregions, a transect along the coastal transition zone used for analysis and the water flow direction in the surface water; (c) annual loads of suspended sediments (SS) from the Pearl River; (d-f) the summertime concentrations of nutrients (DIN, DIP) and dissolved oxygen (DO) in the river outlets of the PRE.

At the same time, based on the added content, we will revise the section discussing the differences in the impacts of SSC and nutrients on hypoxia in lines 524-535:

"It is worth mentioning that the relative importance of the riverine nutrient and SSC changes were different between the two hypoxic centers in the lower PRE, depending upon their distances and water flow conditions from the river outlets. Closer to the river outlets, the Modaomen sub-estuary and its surrounding waters (located on the western side of the coastal transition zone off the PRE) possessed a fairly high SSC level. Suspended sediments were confined to the coastal area of Modaomen by water currents (Fig. 1b), resulting in a significant decrease in sediment deposition in this region, which greatly improved light availability, ultimately making the oxygen dynamics more susceptible to the decline in riverine SSC. On the contrary, the Hong Kong waters and adjacent coastal areas (located on the eastern side of the coastal transition zone) far from the river outlets were less affected by the riverine inputs, where

the relatively low nutrient levels promoted more sensitive responses of biogeochemical processes (e.g. primary production and SOD) and hypoxia occurrences to nutrient variations. Besides, the complex island topography near Hong Kong (Fig1b) creates hydrodynamic barriers that restrict the offshore transport of suspended sediments."

If kept, eq.1 can be written in a more concise way using vectorial notation.

Response: We appreciate reviewer's suggestion and will revise Equation 1 as follows: Line 164: "*As for the oxygen dynamics, it can be described as follows:*

$$\frac{\partial DO}{\partial t} = -\boldsymbol{u} \cdot \nabla DO + \nabla \cdot (\boldsymbol{D} \nabla DO) + Rea + Phot + WCR + SOD$$

where the velocity vector $\boldsymbol{u} = (u, v, w)$, $\boldsymbol{\nabla DO}$ *represents the gradient operator (spatial derivative of dissolved oxygen concentration), and* $\boldsymbol{D}$ *is the diffusion coefficient tensor.* Rea *and* $Phot$, WCR, *and* SOD *represent the rates of air-water oxygen exchange, photosynthesis, water column respiration, and sediment oxygen demand, respectively (unit: mg* O_2 L^{-1} day^{-1}*)."*

L173: If you keep the details about each term, please also include some information about the type of parameterization used for the Rea term.

Response: We will add an equation of Rea as follows:

"*The air-water oxygen exchange is parameterized as:*

$REA = K_a \theta_a^{T-20} \cdot (DO_{sat} - DO)$

where K_a *is the surface mass transfer coefficient (m/day),* θ_a *is the temperature coefficient,* T *is the water temperature, and* DO_{sat} *is dissolve oxygen saturation concentration."*

L269: I'm not sure I understand this claim, given that SSC is an input of the model.

Response: The SSC in this study is derived from the physical module of the coupled 1D-3D model, specifically the ECOMSED model. The ECOMSED model calculates the transport and distribution of SSC in the estuary based on inputs from river outlets. These SSC values are then processed by the RCA model to compute light attenuation, which is a key component of the light model in this study.

In other words, although SSC is an input for the light attenuation calculation in the RCA model, it is dynamically simulated by the ECOMSED model rather than inputting as a fixed value. This approach allows us to capture the spatiotemporal variations of SSC in the estuary, which is crucial for accurately simulating light conditions and their impact on hypoxia.

To improve clarity, we will incorporate additional text in TextS1, Line 87:

"*The suspended sediment input used in the RCA is derived from ECOMSED calculations, enabling dynamic shading calculations in the Pearl River Estuary."*

L272: If I understand correctly, the authors run the model for 8 months, once with the 1990s conditions, and once with the 2010s conditions. This sentence suggests that the suspended sediments from the 1990s has sunk by 2010s, but the two simulations are not connected.

Related to this previous comment, I suggest being careful with the wording throughout this section, since the model is not providing true estimates of changes from 2010s to 1990s, but rather showing how the prescribed changes in riverine input are reflected downstream.

Response: We thank the reviewer for pointing out the potential confusion in this section. As the reviewer correctly noted, the two simulations for the 1990s and 2010s are independent and not dynamically connected. The model does not simulate a continuous transition from the 1990s to the 2010s but rather compares two independent scenarios based on representative input conditions for each period.

Specifically, the SSC for the 1990s and 2010s were calculated separately in the model based on the river inputs and boundary conditions for each period. This approach allows us to reconstruct the biogeochemical conditions of both periods and compare their impacts on hypoxia.

To improve clarity, we will modify the expression there:

"Due to the consecutive sinking along with water transport, SSC decreased to ~10.0 mg/L in the lower reaches of the PRE in the 1990s."

Table 2: What is the definition of bottom waters?

Response: Bottom water refers to the water layer extending from the sediment interface up to 1% of the total water depth. We have added this on the table caption.

L311 and L322: Use the present tense.

Response: We will correct it as advised.

Fig. 4: I strongly suggest adding the difference between the two periods, as in Fig. 3.

Response: To more intuitively compare the differences in euphotic depth and nutrient limitations across subregions between the two periods, we have provided the mean values of these variables in Table 2. However, we agree with the reviewer that difference plots could more effectively visualize these changes. Therefore, in the revised manuscript, we will update Figure 4 by adding difference plots to better illustrate the spatiotemporal variations in growth factors.

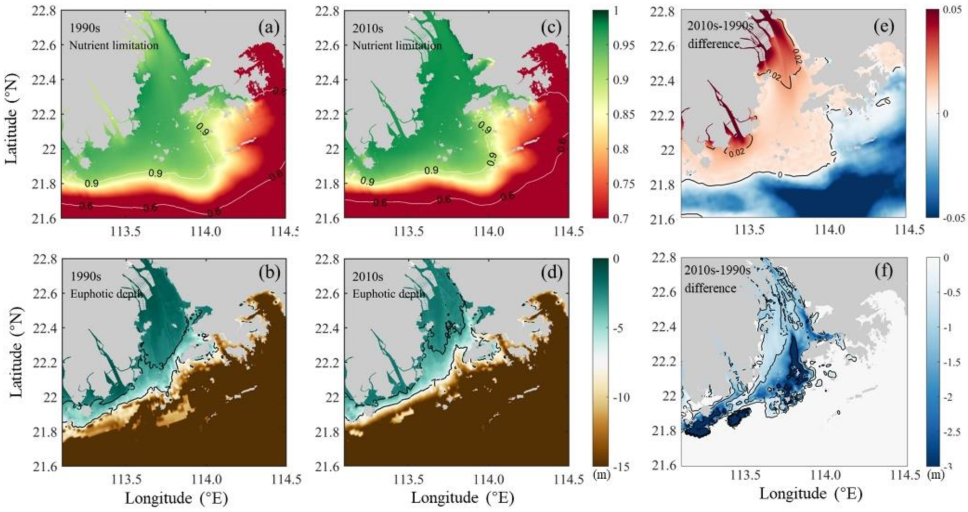


Fig. 4. Simulated distributions (a, c) and difference (e) of nutrient limitation index for the growth of phytoplankton in the 1990s and the 2010s; (b, d) euphotic depth and its difference (e) (in unit of m) in the 1990s and the 2010s.

Fig. 5: I suggest showing the line on Fig. 5a instead of Fig. 1.

Response: We will add the line representing the transect on Figure 5 as follows.

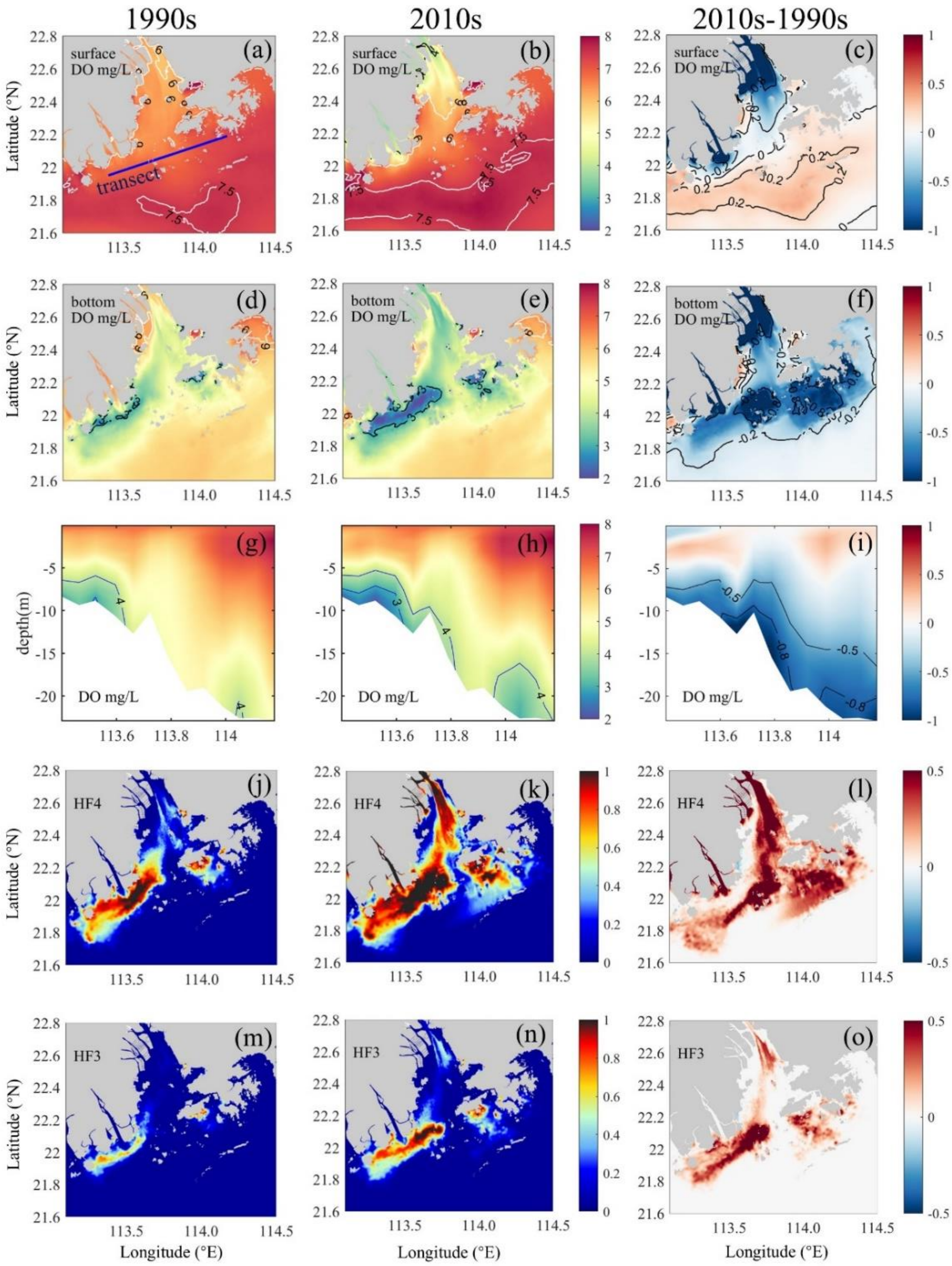


Fig. 5. (a-c) Surface DO and (d-f) bottom DO distributions, (g-i) vertical DO distributions along the transect (see its location in panel a), and (j-l) low-oxygen frequency (HF4, DO < 4 mg/L) and (m-o) hypoxia frequency (HF3, DO < 3 mg/L) in the bottom waters of the PRE for the 1990s (left panels) and the 2010s (middle panels) as well as their differences (right panels).

Fig. 6: I suggest adding contours showing the hypoxic and low-oxygen zones, so we can see if the changes are felt in low-oxygen zones or in well-oxygenated areas.

Response: We will recreate Figure 6, where the blue and white contour lines represent DO = 4 mg/L for the respective cases, and the red contour lines represent DO = 3 mg/L. Since the study did not set up a separate case specifically for freshwater DO input, it is not possible to calculate the low-oxygen area in (d). However, the reduction area caused by freshwater DO input can be determined by comparing it with the low-oxygen area in Figure 5e.

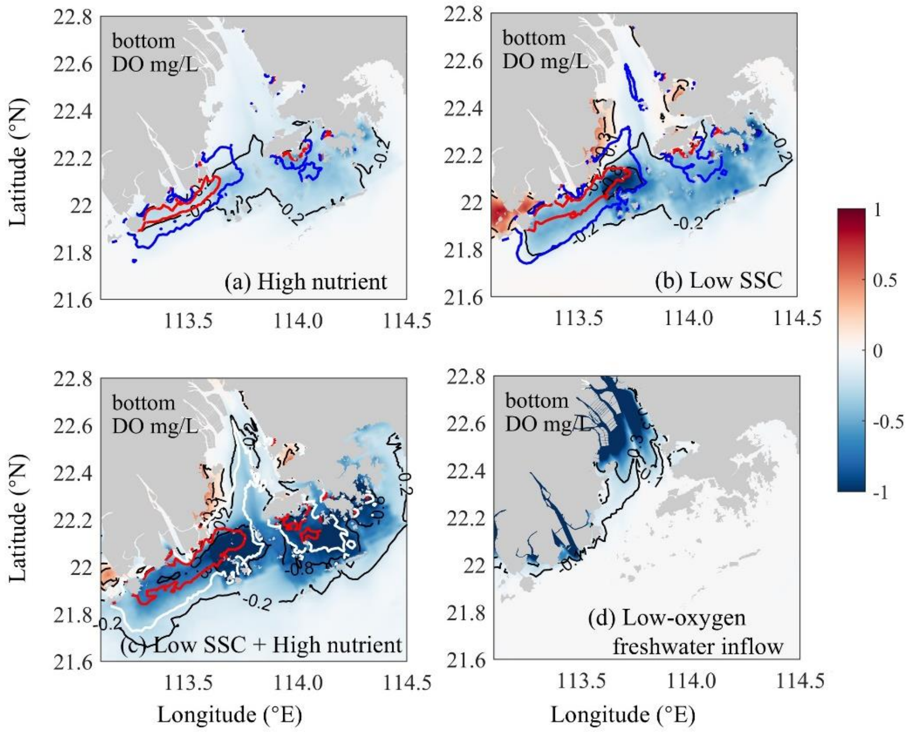


Figure. 6. Bottom DO changes induced by (a) riverine nutrient increases (the High-nutrient case minus the 1990s case), (b) riverine SSC declines (the Low-SSC case minus the 1990s case), (c) the combined effects of nutrient increases and SSC declines (the DO-restore case minus the 1990s case), and (d) riverine DO declines (the DO-restore case minus the 2010s case), respectively. The blue and white contour lines represent DO = 4 mg/L for the respective cases, and the red contour lines represent DO = 3 mg/L.

Fig. 7: I suggest not using a diverging colorscale since the values are not centered on zero. The current colors give the impression that in some areas the values are increasing and in others they are decreasing. I also suggest labeling 2010s as High nutrient + Low SSC, similarly to Fig. 6.

Response: Our original intention was to highlight areas with significant changes in red, but the choice of this color bar indeed caused confusion. Therefore, we will modify the color bar as follows:：

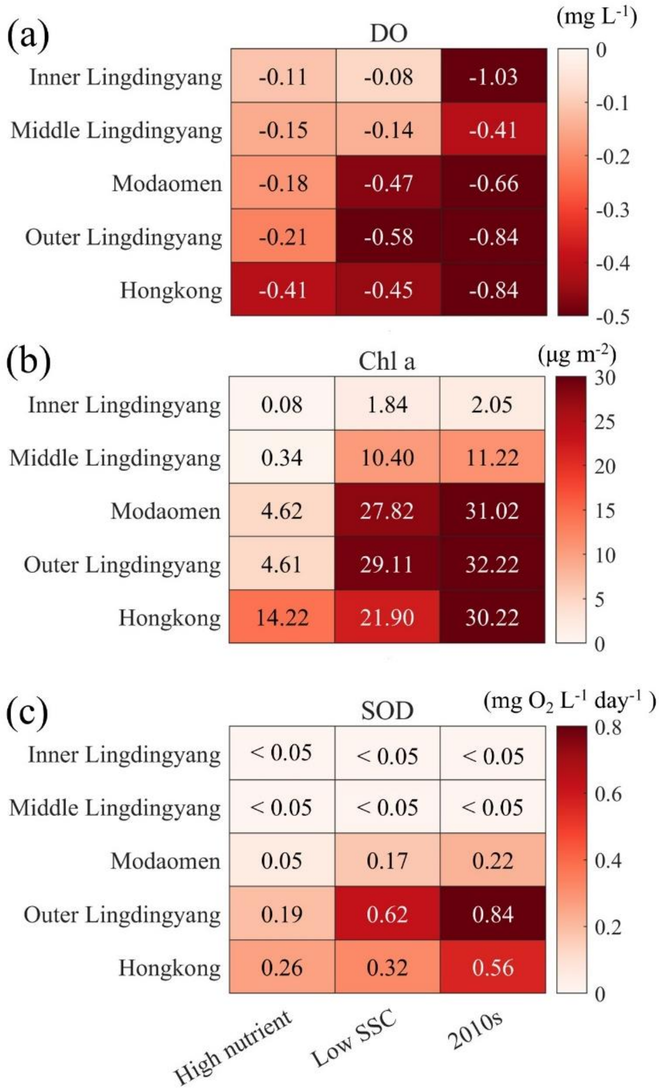


Figure. 7. Changes of (a) bottom DO concentration, (b) vertically-integrated Chl a content, and (c) SOD in subregions of the PRE for the High-nutrient, the Low-SSC, and the 2010s cases relative to the 1990s case.

Regarding the suggestion to label the 2010s as "High nutrient + Low SSC," the 2010s scenario in this study also includes the effects of low-oxygen water from upstream. Changing it to "High nutrient + Low SSC" would omit an important piece of information. Therefore, we choose to stick with the case name “2010s.”

L521: Since you provide a quantification for the role of low-DO input, I suggest also providing a number for the role of SSC versus nutrient loading.

Response: We appreciate the reviewer’s suggestion. We will revise the description as follows:

Line 521: *“Our results also indicated that the riverine SSC reduction played a more important role in driving the long-term low-oxygen expansion in the PRE (Table 3). Its synergistic effect with the riverine nutrient changes could further amplify the* *exacerbation of eutrophication and subsequent deoxygenation, resulting in an enlarged growth in the low-oxygen area (by 104%) and hypoxic area (by 192%) that was notably larger than the total of their partial contributions, and reached 70% of the total impact from combined SSC, nutrient, and low-oxygen changes (148% low-oxygen expansion).”*

I suggest commenting on why the impact on production is so much downstream of the changes in SSC and nutrient concentration.

Response: We will add the following description in the discussion section after Line 521:

“This spatial heterogeneity in regulatory mechanisms highlights the distinct responses of the PRE to environmental changes: light limitation and intense vertical mixing decouple nutrient-productivity relationships in turbid upstream regions, whereas downstream stratified systems exhibit amplified biogeochemical sensitivity through enhanced light availability, nutrient retention, and phytoplankton growth efficiency. These processes collectively underscore the estuary's sensitivity to habitat filtering effects, further explaining the observed expansion of low-oxygen zones.”

There are some repetitions between the first part of the discussion and the conclusion. I think the first part of the discussion could be removed.

Response: We appreciate the reviewer’s valuable suggestion. In revising the manuscript, we have made concerted efforts to streamline this paragraph. However, to ensure clarify for readers and facilitate the subsequent discussion on this study’s core finding, the spatial variability in hypoxia drivers across different regions of the estuary, we will retain a concise summary of key results. The revised paragraph will be:

“By integrating long-term observations with physical-biogeochemical model simulations, we revealed significant bottom-water deoxygenation in the Pearl River Estuary over the past three decades, driven by changes in riverine inputs. From the 1990s to 2020s, summer inflows of DIN and DIP increased by ~100% and ~225%, while SSC decreased by ~60% due to human activities like dam construction (Liu et al., 2022) and reforestation (Cao et al., 2023). Concurrently, oxygen depletion from terrestrial pollutants reduced riverine DO concentrations by 46% (Ma et al., 2024). These shifts collectively intensified bottom-water low-oxygen conditions in PRE (Fig. 5), with model simulations showing a 148% expansion in summer low-oxygen areas (DO < 4 mg/L) and a 192% decrease in hypoxic areas (DO < 3 mg/L). Low-oxygen events also become more persistent, lasting longer (~15-35 days during June-August) and expanding vertically by ~1-4 m and (Table 3).”

Data availability: The authors say in the text that all data are publicly available or coming from other studies. Please provide in this section the link to access each dataset.

Response: We will revise the Data availability as follows. We will also revised the Table S1 of the Supplement for a clearer description (please see responses to General Comments above for the revised table).

“Data availability

The dissolved oxygen observation datasets off the Pearl River Estuary were obtai *ned from published studies (Hu et al., 2021, DOI: 10.5194/bg-18-5247-2021; Su et al., 2017, DOI: 10.5194/bg-14-4085-2017; Li et al., 2021, DOI: 10.1029/2020JC016700) and the Hong Kong Environmental Protection Department (www.epd.gov.hk). The observed nutrients, oxygen, and suspended sediments data in the Pearl River are available from Hu et al. (2021) and publicly accessible databases maintained by China's Ministry of Ecology and Environment (https://www.mee.gov.cn/) and the China River Sediment Bulletin (http://www.mwr.gov.cn/sj/tjgb/zghlnsgb/).*"

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