#Reviewer 2

We thank the reviewers for their valuable comments, which have been essential in improving our study. In response to feedback from several reviewers, we have optimized the parameterization of the advection-dispersion module, allowing us to use a more realistic dispersion coefficient. In the new version of the article, as detailed in the responses to the questions, we have provided a more precise explanation of the dispersion coefficient used. Additionally, a new section (Section 3.1) has been added, where we justify in detail the need to include sinks, as well as provide a thorough description of the sink parameter. All the results presented in the article have been updated to reflect the new simulations performed with the improved model version. Although these new simulations do not alter the results or discussion presented, they contribute to greater clarity and precision in the presentation of the findings.

Thanks to reviewer 2 for their comments and suggestions, and for taking the time to review the manuscript. Please find below the answers:

1. **The authors will need to justify better the use of an 1D model for salt intrusion as this neglects the effect of vertical salinity gradients which contribute to salt intrusion. In this case, a constant diffusion coefficient is not enough to account for any unresolved mixing. In addition, Figure 1b and d show that both the width and the depth of the channel can be significant and so it is dubious if averaging can be justified. Have the authors considered the use of a 2DV model instead?**

Thank you for your comment.

The bathymetric data we used, based on the 2019 nautical chart provided by the Spanish Navy Hydrographic Service (the most recent available), show that the depth varies from 5 to 18 m and the width from 100 to 400 m. This configuration indicates that the cross-sectional areas of the estuary do not show significant variations, considering that the total length of the estuary is 107 km. This allows a simplification of the equations to a 1D model.

Similarly, under conditions of low freshwater flow, the hydrodynamic behavior of the estuary is dominated by the tidal influence (Diez-Minguito et al., 2012). This results in minimal variation in the transverse direction (perpendicular to the flow). The inflow predominantly follows a longitudinal direction, and the transverse variations are small enough to adequately represent the hydrodynamic behavior of the estuary.

This aspect is supported and demonstrated by the hydrodynamic validation presented by Sirviente et al. (2023), which shows an extensive and thorough validation of the 1D hydrodynamic module, illustrating its ability to simulate tidal height and current velocity with high reliability. This study shows how the 1D model is able to reproduce both surface and depth observations from moored current meters. The high reliability of the model indicates that there are no significant velocity variations at different depths, suggesting that vertical mixing is sufficiently strong. This supports the idea that a 1D model is appropriate.

The variability in depth and width is accounted for as the bathymetry is inherently incorporated into the model and averages are used for each section. The effectiveness of this approach is demonstrated in Sirviente et al. as well as in the strong correlations obtained in the present study.

In terms of vertical salinity structure, the estuary is primarily characterized by intense mixing that prevents the formation of significant vertical salinity or temperature gradients (Diez-Minguito et al., 2012), resulting in a homogeneous distribution of water properties. In other words, a well-mixed estuary is defined by uniform salinity mixing due to strong tidal currents, which prevents stratification. Similarly, the vertical circulation shows a relatively uniform flow pattern during low-flow periods, with no significant variations in flow velocity or direction at different depths (Losada et al., 2017). These conditions allow the hydrodynamic equations to be simplified to those of a one-dimensional channel, as validated in previous studies of the Guadalquivir estuary (Álvarez et al., 2001; Siles-Ajamil et al., 2019; Sirviente et al., 2023). The vertically homogeneous salinity behavior is further demonstrated in the answer to the following question and the accompanying figures (Reviewer comment 2).

Regarding the ability of the 1D model to capture the effects of vertical salinity gradients and unresolved mixing processes, it is important to note that in systems characterized by intense mixing and uniform vertical circulation, such as the GRE, a one-dimensional model can adequately represent the hydrodynamic behavior and salinity distribution without necessarily requiring a variable diffusion coefficient.

Thanks to the reviewers' comments, we reviewed and adjusted the transport model to use a higher, more realistic constant diffusion coefficient without introducing instabilities into the model. In the revised version, based on Bowden (1983), we defined the most appropriate horizontal dispersion coefficient, taking into account the mean depth and tidal amplitude. This calculation was performed for all campaigns included in the analysis to ensure the use of a constant dispersion value appropriate for the system. The results indicate that the maximum constant dispersion based on velocity and depth is 150 m²/s (this has also been added and explained in detail in the revised version of the article). In addition, a sensitivity analysis was performed with different dispersion coefficients to optimize this parameter as much as possible. It was found that a dispersion value higher than 200 m²/s leads to numerical instabilities in the system.

Based on Bowden (1983), the effective horizontal dispersion coefficient can be calculated as $K_X=U^2H^2/30*K_z$, where *U* is the maximum tidal velocity, *H* is the mean channel depth, and *Kz* is the vertical eddy dispersion coefficient, assumed to be constant. In our case, we used *Kz*=0.01, as proposed by Bowden (1983).

Campaign	U (ms^{-1})	K_x m^2s^{-1}
MG1	0,85	143
MG2	0,88	154
MG3	0,88	153
MG4	0,80	127

Furthermore, given the lack of comprehensive data on the coefficient's variability across the estuary, it was determined that a constant value would be an adequate representation of the general conditions. Finally, model validation with observational data has demonstrated that employing a constant coefficient is an effective method for accurately reproducing the essential characteristics of the system, thereby supporting this approach within the context of the present study. Furthermore, numerous studies in the literature have demonstrated that models with a constant dispersion coefficient are capable of accurately reproducing salinity distributions (e.g., Lewis and Uncles, 2003; Brockway et al., 2006; Gay and O'Donnell, 2007, 2009; Xu et al., 2019; Siles-Ajamil et al., 2019; Biemond et al., 2024). This choice not only maintains the stability of the model, avoiding numerical instabilities, also ensures that the results are consistent with theoretical expectations and experimental observations.

Regarding the use of a 2D model, although we have not explicitly applied a 2D model to the Guadalquivir estuary, we have analyzed its analytical solution. This approach allows us to observe that the differences in velocity in the longitudinal direction of the estuary are not significantly different from those obtained with the 1D version.

In Figure R1, we present the analytical solution for a channel-cross section using a 2D model that includes the channel width and a parabolic depth variation that approximates the change in depth from the lateral boundaries to the center of the channel. For comparison, we also include the 1D solution for the same channel (length = 5 km, width = 525 m, 2-day simulation) with an average depth of 6.7 m.

As shown, there are differences at the lateral boundaries, within the first 100 m on either side of the channel. However, the oscillations are not significant, and the velocities are very similar across most of the channel width. This shows that the behavior is generally homogeneous, validating the 1D solution. This conclusion is confirmed by the average velocities obtained for each solution at different times (Table R1), where the differences between the average velocities of the two models are minimal.

It is true that using the 1D solution slightly underestimates the velocity in the center of the channel and slightly overestimates it at the boundaries. However, these discrepancies do not affect the results, as the model has been shown in Sirviente et al. (2023) to reproduce the observations with high reliability.

This reinforces the idea that the use of a 2D model does not provide a substantial improvement over the 1D model.

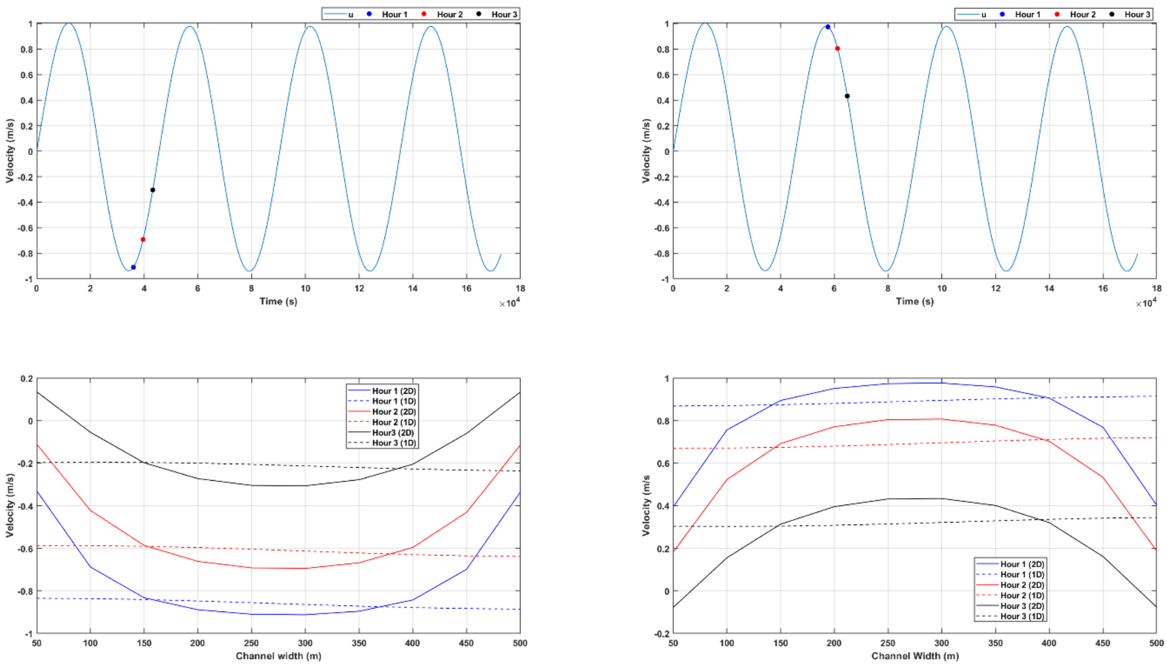


Figure R1. The top panels display the time series of the longitudinal velocity (uu) for section 20 of the channel. Colored markers highlight the three consecutive hours analyzed in the bottom panels. The bottom panels compare the velocity profiles obtained from the 2D model (solid lines) with those from the 1D model (dashed lines) at the selected times, illustrating the differences across the channel width.

Table R1. Average Velocity in Section 20 of the Idealized Channel for 2D and 1D Simulations Over a 6-Hour Period (3 Hours of Flood Tide and 3 Hours of Ebb Tide)

	u average 2D (ms^{-1})	*u average 1D* (ms^{-1})
Flood Hour 1	-0.75	-0.86
Flood Hour 2	-0.52	-0.61
Flood Hour 3	-0.16	-0.21
Ebb Hour 1	0.82	0.89
Ebb Hour 2	0.62	0.69
Ebb Hour 3	0.26	0.32

We appreciate the reviewer's suggestion and will take it into account for future work.

Biemond, B., de Swart, H. E., & Dijkstra,H. A. (2024). Quantification of salttransports due to exchange flow and tidalflow in estuaries. Journal of GeophysicalResearch: Oceans, 129, e2024JC021294. https://doi.org/10.1029/2024JC021294

Bowden, K. F. (1983). *Physical Oceanography of Coastal Waters*. Ellis Horwood Series in Marine Science. E. Horwood. [University of Michigan, Digitized Nov 3, 2007]. ISBN 0853126860, 9780853126867.

Brockway, R., Bowers, D., Hoguane, A., Dove, V., and Vassele, V.: A note on salt intrusion in funnel–shaped estuaries: Application to the Incomati estuary, Mozambique, Estuar. Coastal Shelf S., 66, 1–5. https://doi.org/10.1016/j.ecss.2005.07.014, 2006.

Gay, P. and O'Donnell, J.: A simple advection–dispersion model for the salt distribution in linearly tapered estuaries, J. Geophys. Res., 112, C07021. https://doi.org/10.1029/2006JC003840, 2007.

Gay, P. and O'Donnell, J.: Comparison of the salinity structure of the Chesapeake Bay, the Delaware Bay and Long Island Sound using a linearly tapered advection–dispersion model, Estuaries Coasts, 32, 68–87. https://doi.org/10.1007/s12237-008-9101-4, 2009.

Lewis, R. E. and Uncles, R. J.: Factors affecting longitudinal dispersion in estuaries of different scale, Ocean Dynam., 53, 197–207. https://doi.org/10.1007/s10236-003-0030-2, 2003.

Xu, Y., Hoitink, A. J. F., Zheng, J., Kästner, K., and Zhang, W.: Analytical model captures intratidal variation in salinity in a convergent, well-mixed estuary, Hydrology and Earth System Sciences, 23, 4309–4322. https://doi.org/10.5194/hess-23-4309-2019, 2019.

2. **There is an inconsistency in the terminology. In some instances, the authors refer to salt intrusion and in others to salt wedge or even salt front and it seems they don't distinguish between these terms. I would advise to remain consistent throughout the manuscript and give an explicit definition. Salt intrusion is usually measured as the landward penetration of a bottom isohaline while the salt wedge is defined as a bottom layer of denser than the surface water. Consequently, I reckon that what is seen in the figures is rather the salinity horizontal gradient (or salinity front) instead of salt intrusion or wedge. Furthermore, the model results are compared with observations taken at 2m below the surface, but the depth can be much deeper in certain sections as it can be seen in Figure 1b. Therefore, I think it is possible that the discrepancy observed between model results and observations without the sinks may be due to the depth averaging which may moderate higher bottom salinity.**

We appreciate the reviewer's comment and agree that the terminology used throughout the manuscript was inconsistent. We have corrected this by replacing all related terms with "salt/saline intrusion," as we believe that in a well-mixed estuary, this is the most appropriate term to describe the extent of saltwater moving upstream. We have also replaced it with "horizontal salinity gradient" when referring to longitudinal variations in salt concentration, as this term describes how salinity changes as one moves horizontally through the estuary. We believe these corrections will clarify the use of these terms and avoid potential confusion.

We apologize for the errors in the original wording.

Salt/Saline intrusion refers to the upstream movement of saltwater into freshwater areas, particularly during low river flow or high tides.

Horizontal salinity gradient: Variation in salt concentration in the water over a horizontal distance in the estuary.

“Therefore, I think it is possible that the discrepancy observed between model results and observations without the sinks may be due to the depth averaging which may moderate higher bottom salinity. “

We appreciate the comment, but we believe that in this particular case, the observed discrepancy between the model results without the sinks and the observations is not due to the depth averaging.

The estuary we are modelling is characterized by being well mixed, with minimal vertical salinity gradients. In this type of system, vertical mixing is strong enough to maintain a relatively homogeneous salinity throughout the water column. Therefore, we believe that the depth averaging used in the model is an adequate representation of the actual conditions in the estuary, as it reflects the homogeneous nature of the salinity distribution observed in the field.

It should be noted that this is valid in our study because we are in low freshwater discharge conditions (all the campaigns analyzed in this study). Under high discharge conditions, this approach would not be valid because the water column would not be perfectly mixed. Therefore, in this study, we only analyze the low flow cases which correspond to approximately 80% of the year.

We appreciate your comment and understand the concern about the potential impact of depth averaging in systems with more pronounced vertical gradients. However, in this particular case, we believe that the current approach is valid for representing salinity conditions in the well-mixed estuary.

In the validation of the hydrodynamic model (see Sirviente et al., 2023), observations were validated with both state harbor tide gauges, which measure at the surface, and current meters, which are anchored at various points. The high reliability of the simulations with all observations indicates that the 1D model is able to reproduce u and η with a high degree of accuracy, thus demonstrating that the model approach of using depth averages in this way is appropriate. This indicates that there is homogeneity in velocity, meaning that there are no significant gradients causing stratification, which means that the estuary is well mixed.

To understand this in terms of salinity, since there is no evidence of velocity stratification, we can assume that vertical salinity gradients are minimal and that salinity concentrations are homogeneous throughout the water column. Therefore, the comparison between simulations and observations is appropriate, and the differences between simulations without sinks and observations are not due to depth averaging.

The vertical mixing and the reduced salinity gradient are evidenced by the data recorded by the CTD during each campaign. CTD profiles were performed at the different sampling points shown in Figure 1 of the manuscript, allowing us to analyze the vertical behavior of the salinity. The figures below correspond to the vertical salinity profiles measured during the MG1, MG2 and MG3 campaigns.

For MG3, CTD profiles were taken at 1-hour intervals over two tidal cycles, for a total of 25 hours at each site. For the MG1 and MG2 campaigns, measurements were taken at 1-hour intervals for a maximum of 10 hours. The sampling points for MG3 are the same as those shown in Figure 1 of the manuscript, as is the case for MG2. However, for MG1 there are more CTD sampling points than shown in the figure. The points for MG1 shown in the CTD plots correspond exactly to the positions of MG2 (see Figure 1a of the manuscript). It should be noted that there are no vertical profiles available for MG1-1 and not all sampling stations have 10 profiles.

When analyzing the behavior of the vertical profiles, it can be observed that in MG3 the water column always remains mixed, showing only very slight vertical salinity gradients during certain hours. The MG3 figure shows that vertical mixing prevails during the tidal cycles. Similarly, during the MG2 and MG1 campaigns, a strong vertical mixing is observed throughout the water column at all CTD profiles in all points of the river.

This observation was essential in simplifying our approach, allowing us to adopt a one-dimensional (1D) model, assuming that the salt concentration is homogeneous throughout the water column. We would like to emphasize that this strong mixing behavior is not always characteristic of the estuary. This intense mixing occurs under low discharge regimes, where freshwater flow is minimal and tidal dominance is evident (as in our study case). In scenarios with moderate or high discharge regimes, the vertical salinity gradient behaves differently, leading to stratification of the water column. Under such conditions, this model cannot be applied as it would underestimate the salinity levels.

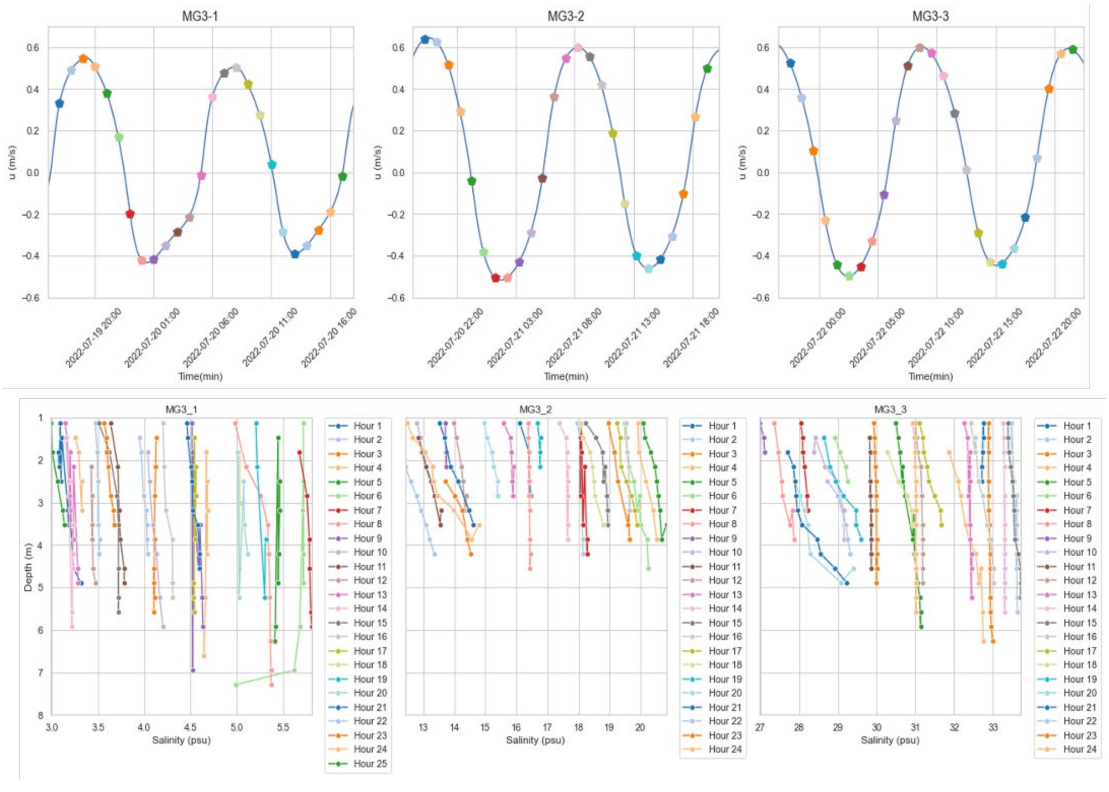


Fig. R1. Top panel corresponds to the tidal current velocity at each sampling station during the MG3 campaign, with different colors indicating the tidal phases during which each CTD profile was taken. The bottom panel displays the CTD profiles at each sampling point along the Guadalquivir River during the MG3 campaign.

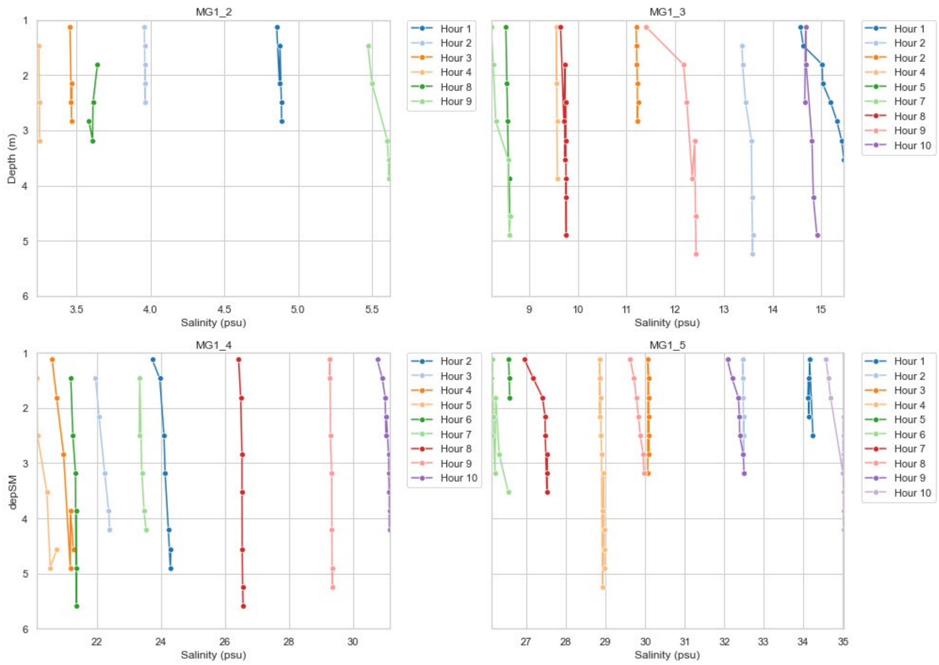


Fig. R2. **C**TD profiles at each sampling point along the Guadalquivir River during the MG2 campaign.

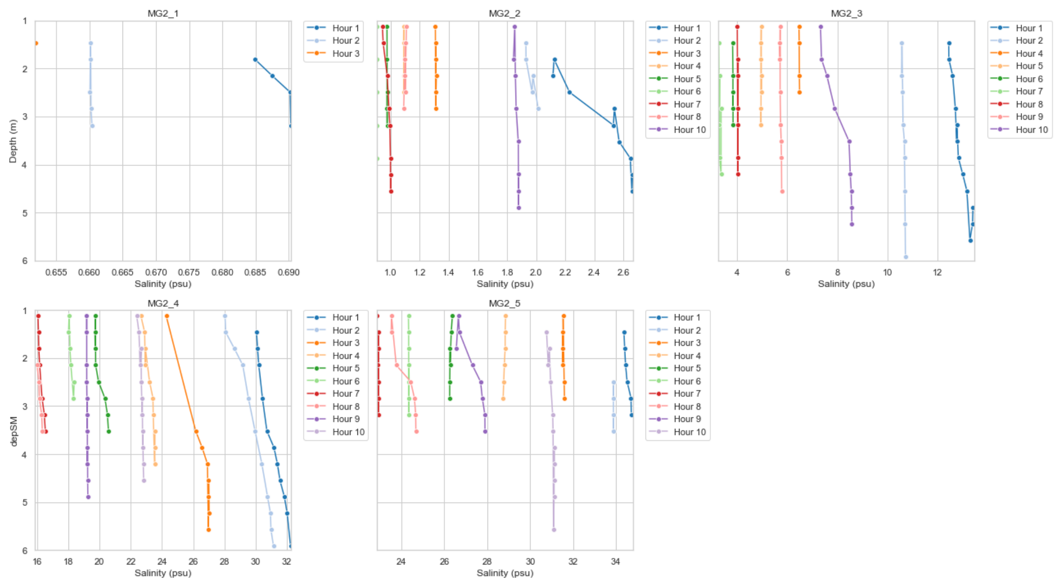


Fig. R3. **C**TD profiles at each sampling point along the Guadalquivir River during the MG1 campaign.

These figures will be added to the manuscript as supplementary material SM1, SM2 and SM3 (only the points coinciding with the thermosalinograph fixed stations and presented in figure 1a of the manuscript). We will adjust the nomenclature of the other supplementary material figures in the text to ensure that they are in the correct order. We have added these lines to the text:

<ins>Line 180 :</ins>

"CTD profiles obtained at the same sampling stations as the thermosalinograph data for campaigns MG1, MG2 and MG3 shown in Figure 1a are also used. These profiles are used to analyze the vertical behavior of the water column."

Line 275:

"The salinity profiles obtained from the CTDs show a strong vertical mixing of the water column throughout the whole period and at all points (see Figures SM1, SM2 and SM3). Very reduced vertical salinity gradients can be observed, which allows us to conclude that the vertical behavior of the water column in the GRE is homogeneous under these conditions, allowing the use of a 1D model to simulate the salinity concentration along the river."

3. **In continuation to the previous comment. The authors assume that the salinity deficit in their uncalibrated model is exclusively due to water withdrawals. I appreciate that this is an important parameter and even more true for this specific study case, but I believe that the assumption neglects all the other complex physical processes and mechanisms taking place in an estuary. The authors already mention in their manuscript tidal amplification and channel deepening. Don't these two also account for an upstream increase in salinity?**

We appreciate your comments and observations. Indeed, the increase in channel depth and tidal amplification in the upper estuary will contribute to the increase in salinity. However, in our simulations we analyze the actual salinity concentration at the time of the campaign, which already accounts for tidal amplification, and we use the most recent actual depth available, which allows us to account for both processes.

These two factors can explain an increase in salinity upstream over time, as the channel geometry changes. But we are convinced that these are not the only factors that play a role in the increase of salinity in the estuary. Rather, freshwater flow and withdrawals from anthropogenic activities play a fundamental role.

Therefore, we believe that the salinity deficit between the model without sinks and the observations is mainly due to the lack of consideration of the parameter δ. The parameter δ is a key factor in quantifying the effect of extractions and small contributions of water along the river. In other words, this factor allows us to consider all activities related to the reduction or increase of water volume in the channel (extractions for domestic use, agricultural use, industry, small channels that flow into the estuary, etc.).

It represents an average value between these two actions and has been shown to be positive for our study, indicating that, on average, the extractions exceed the contributions of water to the main channel from the small channels that converge in it. Without the inclusion of δ, we observe that the horizontal salinity gradient is considerably lower than that recorded with the observations.

To clarify and enhance the explanation, we have added a subsection within the *Results* section corresponding to Section 3.1, where we demonstrate the necessity of including sinks to achieve the salinity concentrations observed.

If we analyze the behavior of the horizontal salinity gradient along the estuary, taking into account only the horizontal dispersion, we can see that the system would never reproduce the observed salinity concentrations in the different campaigns. Even when the dispersion coefficient is increased to 190 m^2/s, the behavior remains the same. Over time, we observe that salinity in the inner part of the estuary tends to increase; however, it never reaches the observed concentration levels. Therefore, it can be said that horizontal dispersion alone does not achieve the high salinity values observed along the channel, which opens the hypothesis that some additional effect is likely to cause a greater penetration of saline intrusion into the estuary. (Fig R4 (a) & (b))

If the same experiment is carried out but the parameter δ (representing all the processes that reduce the volume of water in the estuary) is included (Fig. R4 c-f), the results show that the system reaches the observed salinity values over time. This shows that this term must be included in order to reproduce the salinity concentrations observed in the different campaigns.

Figures R4c and R4d present the experiments that include water withdrawals as a constant value in time and space (δ = 0.005 mm). As shown, as the simulation time progresses, the system achieves the salt concentrations range presented in the observations. This contrasts with the previous cases, where only the dispersion term was included in the experiments (Figures R4a and R4b), and the observed range could not be achieved.

On the other hand, Figures R4e and R4f show the experiments employing time-varying δ. In this simulation, a stronger sink is applied during the first three days (δ = 0.01 mm), which is then reduced and held constant for the remainder of the simulation (δ = 0.001 mm). In this case, the obtained values closely match those recorded in the observations.

These experiments highlight the necessity of including this term (δ) in the simulations, as otherwise, the horizontal salinity gradient would never reach the observed values. As illustrated in the figure, a certain duration of sink activity is required for the simulated salinity concentrations to approach the range observed. Therefore, it is essential to define an initial condition that considers this progression, allowing the simulation to adequately capture the evolution of the water withdrawals and their impact on salinity over time. This is particularly justified by Figures 4e and 4f, where using a stronger δ during the first three days followed by a weaker δ reproduces the observed behavior.

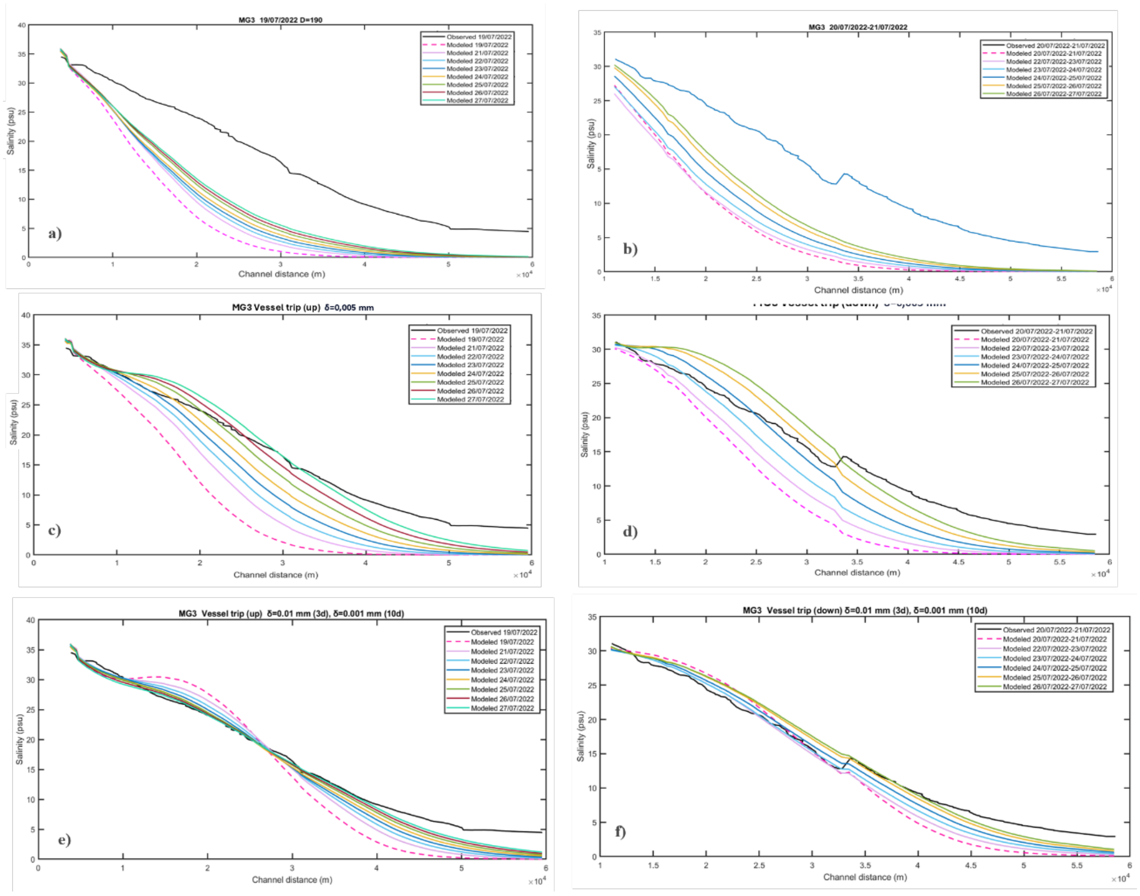


Fig. R4. Comparison of simulated (temporal behavior of the simulation at the corresponding observation points) and observed salinity over the MG3 vessel trips: (a) and (b) show simulations including only the horizontal dispersion for the MG3 vessel trip upstream (a) and downstream (b), with the observations in black. (c) and (d) show simulations incorporating δ term (δ) for the entire simulation period as constant value, and (e) and (f) are the simulation including a time-variying δ, compared to the observations (in black) for the MG3 vessel trip upstream (c and e) and downstream (d and f).

The δ value was determined empirically during the calibration process, through a sensitivity analysis in which different δ values were tested in simulations to identify the one that produced concentrations within the observed range while maintaining the temporal and spatial stability of the model.

Once the δ value was identified, experiments were carried out to analyze its behavior. These included constant use of the parameter over time, and experiments including them at specific time intervals, as well as spatial distribution experiments where δ was applied to specific points (e.g. high areas of the river) and regions. However, due to the limited understanding of the true behavior of these processes, and to avoid introducing assumptions or speculation that could affect the validity of the results, it was considered more appropriate to use a constant value rather than additional assumptions.

As observed, when sinks are included in the model, a certain amount of time is required for the system to reach the salinity concentrations observed. This behavior is represented in the model by an initial condition, designed as a logistic curve, which describes how the effect of the sinks manifests and evolves over a given period of time. This curve makes it possible to simulate the gradual adaptation of the system until it reaches the observed concentrations, providing a useful tool for evaluating and validating the model.

The choice of a logistic curve is justified by its ability to model gradual processes, which makes it suitable to reflect the temporal behavior of the sinks and their impact on the estuarine system. Therefore, the use of this parameter (δ) is an efficient way to quantify the inflows and outflows of water from the main channel, largely due to anthropogenic activities.

To evaluate the effects derived from the tidal wave amplification at the head and the increase in depth, simulations using historical bathymetries, as presented in Sirviente et al. (2023), should be conducted. Similarly, observations from those periods are needed to understand the salinity concentration in the estuary at that time. Future studies aim to assess these effects by conducting experiments that modify the channel geometry, following the experimental approach outlined in Sirviente et al. (2023).

Nevertheless, the fact that these factors may contribute to the upstream salinity increase does not justify the observed discrepancies between the simulation without sinks and the observations. The aim of this article is to highlight, through these numerical simulations, the pressure that anthropogenic activities exert on the salinity concentration in the estuary.

In the following figure (Fig. R5) we present an experiment where we simulated the observations of MG1, using a constant depth and width channel, without including the parameter δ. As you can see, there is a slight variation compared to the simulation where we used the actual depth of the estuary (simulation without δ). This is of particular interest because it allows us to roughly observe the effect of increasing the river depth; however, it is unable to reproduce the salinity concentrations observed during these campaigns

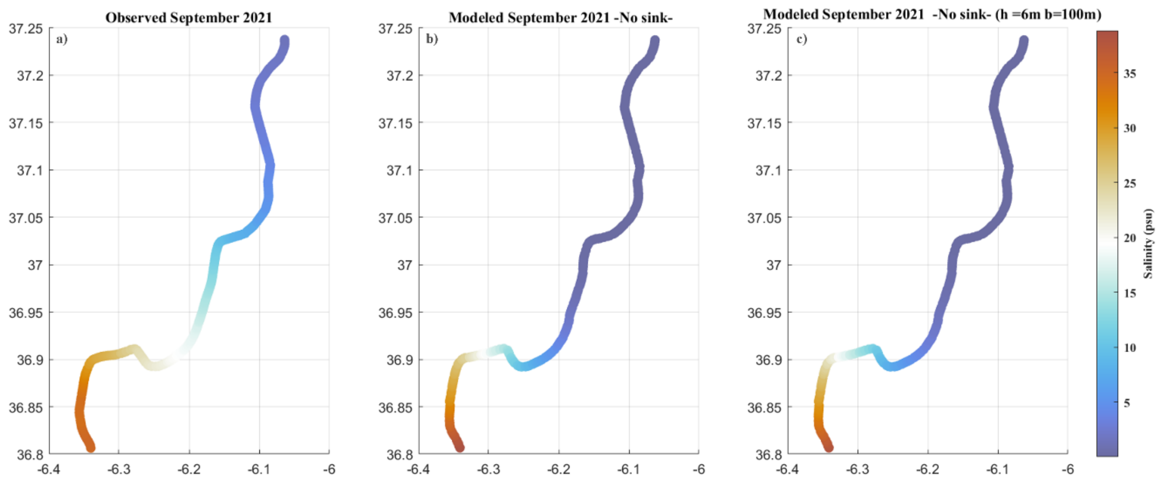


Fig. R5. Observed horizontal salinity gradient during the MG1 campaign (September 2021). (b) Modeled horizontal salinity gradient using the 2019 nautical chart bathymetry. (c) Modeled horizontal salinity gradient for the MG1 campaign using a constant bathymetry (depth = 6m, width = 100m).

4. **The salt transport module was run for the periods when observations from the measurement campaigns that took place between 2021-2023 where available but the hydrodynamic model is forced with data from 2019! How is this justified? This could be already a source of errors.**

Thank you for your comment.

It is important to clarify that the hydrodynamic model is not forced with data from 2019. In reality, the model is forced at the mouth with the predicted sea level corresponding to the date of each campaign. This prediction is based on the tidal harmonics from the Bonanza tide gauge for the entire year 2019, selected because they were the most recent available at the time of designing and implementing the model in the estuary in early 2022. The data used comes from the Bonanza tide gauge of *Puertos del Estado*, and currently, if one accesses the database, the latest complete data available is from 2022.

The decision to use the 2019 data is based on the fact that the discrepancies between the two series are minimal and will not generate significant changes in the simulations (as demonstrated below).

Fig. R6 presents the series of differences between the sea level predictions for MG3 (13 days of July 2022) using the harmonics of 2019 and 2022. As can be seen, the differences between both series are small and statistically non-significant.

Furthermore, in light of the validation of the hydrodynamics presented in Sirviente et al. (2023), it is evident that the predictions calculated for the corresponding dates, based on the 2019 harmonics from the Bonanza tide gauge, allow for the generation of reliable simulations. All of this reinforces our hypothesis that using the 2019 harmonics is valid and does not introduce a significant error into our study.

Furthermore, using the harmonics of 2019 allows us to maintain the same methodology employed in Sirviente et al., 2023. Where the high reliability of our hydrodynamical model is presented.

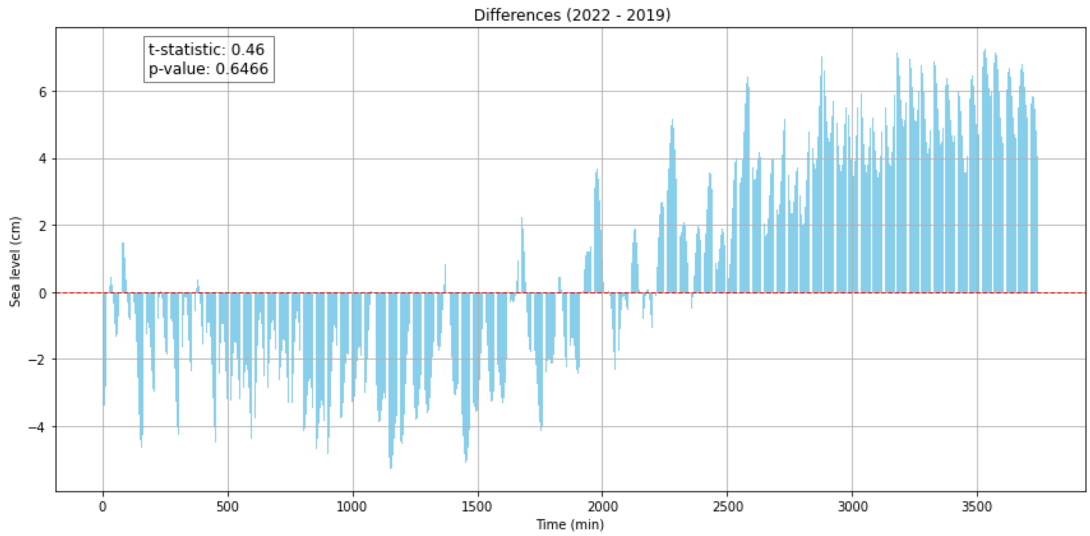


Fig. R6. Observed horizontal salinity gradient during the MG1 campaign (September 2021). (b) Modeled horizontal salinity gradient using the 2019 nautical chart bathymetry. (c) Modeled horizontal salinity gradient for the MG1 campaign using a constant bathymetry (depth = 6m, width = 100m).

Minor comments

1. **I understand the notation used throughout the manuscript as km 60, km 40 etc. but it doesn't read very well. It is better if it is written as 60 km from the mouth, 40 km from the mouth etc.**

Thank you for the suggestion, we have modified the notation following your recommendation.

2. **Please use superscript numbers when giving units (e.g., lines 48, 50 ,197 etc.)**

Done, thank you

3. **Where are the river flows implemented?**

These tributaries flows (river flows) are included in the upper part of the estuary (last section) as they discharge close to this area. Therefore, the sum of these three flows is the freshwater input to the estuary, specifically at its head point, which is indicated in Figure 1 by a black triangle marked "dam".

Thanks to your comment, we have realized that this information was not clearly defined in the manuscript. For greater clarity, the exact location of these tributaries is indicated now in lines 161-165.

4. **It is implied that there is no freshwater input from the upstream boundary which is set at the dam. Is this realistic? Is it true for every season?**

As mentioned in the previous response. We have included three sources of freshwater in the main channel. These inputs are summed in the last section of the model, which corresponds to the head.

Of these three inputs, the most significant flow comes from the Alcalá del Río dam. However, we have also decided to include the contributions from the tributaries Rivera de Huelva and Zufre, despite their relatively small discharges. This decision was made to represent the freshwater input as realistically as possible. Other tributary flows that enter the main channel were not considered, as their discharges during the simulated time intervals were negligible.

The discharge data are obtained from the database of the *Confederación Hidrológica del Guadalquivir* (Guadalquivir SAIH, https://www.chguadalquivir.es/saih/, last accessed: March 25, 2024). This information allows us to demonstrate that our experiments were conducted under low flow conditions, as they present discharges of $Q < 40$ m^3/s.

We understand that all relevant flows should be included, except for those that present a negligible volume for the time interval being simulated.

5. **In Line 90, I think the authors of this paper refer to salt intrusion length and not duration.**

   We appreciate your comment and apologize for the error. Indeed, we intended to refer to the length of salt intrusion, but the wording of the original sentence could lead to confusion. We have corrected the error and modified the sentences as follows:

   "Their results indicate that the mean length of salt intrusion would increase by approximately 8% under the expected scenario of a 15% decrease in freshwater discharge over the next 15 years."

   Thank you for the comment.

6. **There is a confusion in the manuscript. In some instances, the authors write that the maximum salt intrusion corresponds to the flood and in others to the ebb tide. For example:**

Lines 324-325 the authors write ‘ The maximum and minimum extent of the saline wedge within the channel coincided with moments just before high and low tides respectively’. In the next paragraph they write ‘ during the flood tide the wedge demonstrates minimal intrusion in the estuary …… during the ebb tide, the maximum saline intrusion occurred’.

Line 375-376 ‘ the maximum ebb current and the maximum flood current which closely correspond to the maximum and minimum salt wedge intrusion, respectively’.

But then a few lines further down:

Line 380 ‘ During maximum ebb current (just after low tides), when minimum salt wedge intrusion occurs……during flood tides (just after high tides), the maximum salt intrusion is present’.

In the legend of Figure 5 ‘The solid lines represent the time of maximum salinity (F,Flood) and the dashed lines represent the time of minimum salinity (E,Ebb).’

At least, Figure 4a shows that the maximum salinity corresponds to the flood tide which is reasonable for a well-mixed estuary.

Thank you for your comment; you are absolutely correct, and we sincerely apologize for the error in the text. As you mentioned, the maximum (minimum) penetration occurs during the high (low) water slack. However, it is important to note that there is a time lag of 1.5 hours between the two series. We appreciate the reviewer pointing out this oversight.

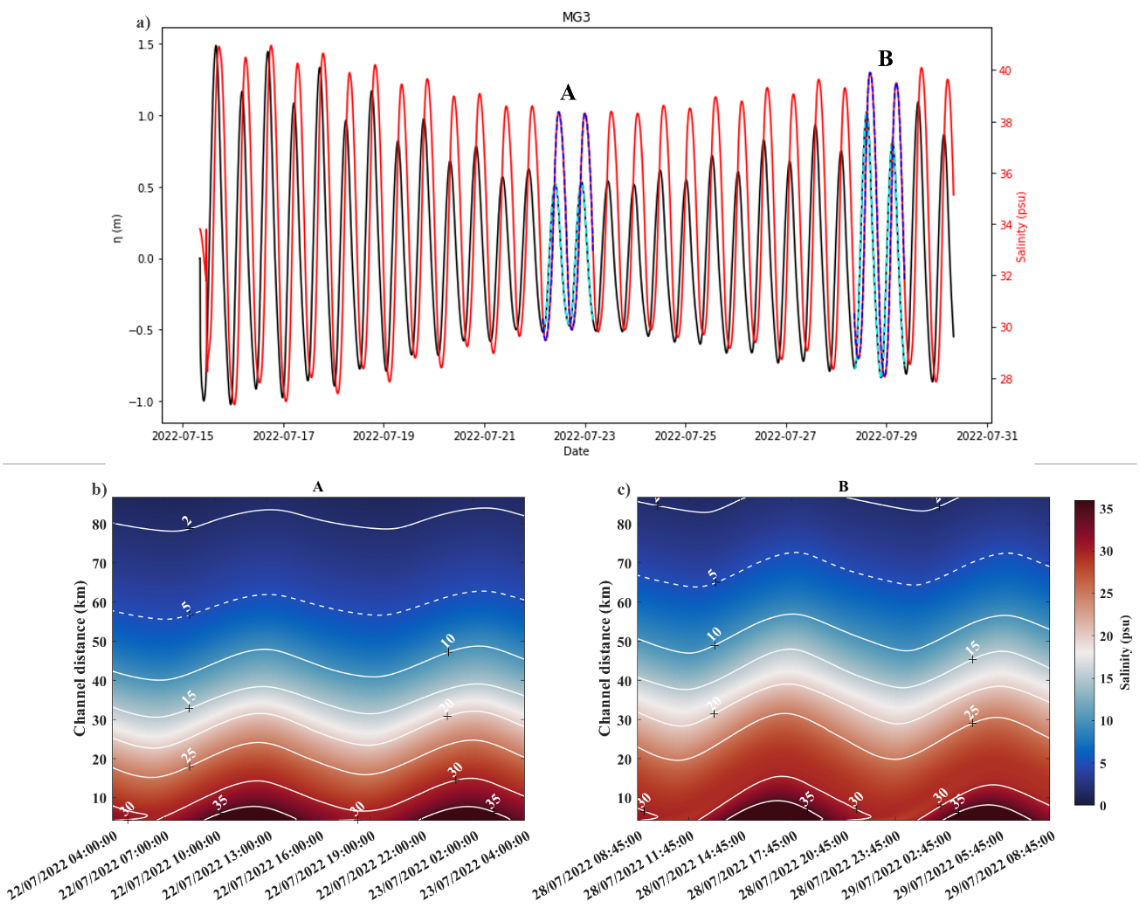
To improve the precision of the analysis and ensure greater clarity in the results, both the figure and the text of section 3.3 have been revised. This section is now presented as section 3.4, utilizing the updated model configuration. Moments of spring and neap tides have been selected instead of the intermediate tides previously used, enabling a more accurate and comprehensible analysis.

The section has been rewritten in alignment with all the reviewers' comments.

“3.4. **Tidal cycle dynamics.**

Once the reliability of the model had been confirmed by the results of the experimental validation presented in the previous sections, it was used to simulate the dynamic of the salinity intrusion during a spring-neap tidal cycle. To do this, we conducted a simulation extended over 15 days (15/07/2022-30/07/2022) using the same model configuration presented in section 3.1 for the MG3 campaign. This period was selected because it comprised records of observations distributed throughout the spring-neap tidal cycle, allowing for the validation of the simulations.

We focused on two 24-hour periods to describe the dynamics of the horizontal salinity gradient during different phases of the semi-diurnal cycle (Fig. 4a). A lag of about 1.5 h was observed between tidal height and salinity profiles (Fig. 4a), which means that the maximum and minimum salinity concentration values coincide with high water slack moments and with low water slacks moments, respectively. Fig. 4b and d, shows a gradual decrease in salinity values upstream.



In Figure 4a, it can be observed that the maximum salinity levels occur near the high water slack, while the minimum salinity levels are recorded around the low water slack. Figure 4b shows the progression of the saline intrusion during neap tides (A). Using the 5 psu isohaline as the boundary for the horizontal salinity gradient, it can be seen that the maximum salinity extends up to 63 km from the mouth, while the minimum values of this isohaline do not exceed 56 km. In contrast, during spring tides (B) (Figure 4c), as expected, higher salinity values are observed throughout all sections of the estuary compared to neap tides. The 5 psu isohaline extends up to 72 km from the mouth, while the minimum values do not exceed 65 km. This shows a difference of approximately 5-8 km between the moments of maximum and minimum intrusion, being this displacement higher for spring tides than neap tides.

In the same way, when comparing the behavior during spring tides to neap tides, we can observe a difference of 8 km between the minimum values and up to 10 km between the maximum values. Therefore, there is an oscillation of approximately 10 km between spring and neap tides. During spring tides, the horizontal salinity gradient reaches higher concentrations further upstream compared to neap tides, where both the maximum and minimum salinity values are lower. This finding is consistent with the results suggested by Díez-Minguito et al. (2013), who documented a net displacement of approximately 10 km between spring and neap tides.

The system is unable to expel the saline wedge during the low freshwater regime, resulting in the formation of a saline plug at the estuary's mouth. This prevents the outflow of internal waters towards the continental shelf of the Gulf of Cádiz, potentially affecting water quality and species in the estuary. However, it should be noted that the model does not resolve the vertical segregation of the flow, which could be important in the lower part of the estuary and affect flushing times there. This conclusion is supported by the positive mass balance at the estuary's mouth (185.41 m^3s^{-1}).

These results suggest that the constant anthropogenic pressure on the estuary has caused a change in the horizontal salinity gradient, resulting in higher salinity levels upstream of the river compared to the records of previous studies, Fernández-Delgado et al. (2007) found that over a six-year period (1997–2003), the 5 psu isohaline boundary was located near 25 km at low tide and at 35 km at high tide. The 18 psu isohaline limit was also found to be 5 km and 15 km upstream of the river mouth at low and high tides, respectively."

Lines 375-378 and Lines 380-385, Now correspond to lines 522 to 532:

"The resulting simulations were analyzed at two specific moments of the tidal cycle at Bonanza station: The resulting simulations were analyzed at two specific moments of the tidal cycle at Bonanza station: at high water slack (continuous lines) and at low water slack (discontinuous lines), which closely correspond to maximum and minimum salinity values, respectively (Fig. 6a and 6b). The Original freshwater flow presented in both campaigns (MG2 and MG3) is used as reference case (Experiment -i-). A 50% reduction in freshwater flow (ii) presented for the MG2 simulation barely differs from the current state (Fig. 6c, blue lines), with a maximum difference of 0.5 psu for both tidal instances. The highest increase is found in the experiment (iii) (Fig 6c, cyan lines), where the freshwater flow is cancelled. As seen in Fig. 6c, maximum changes do not exceed 0.9 psu. During low water slacks, when minimum saline intrusion occurs, the zone with the highest differences for both experiments is within the first 20 km from the mouth. Conversely, during high water slack moments, the maximum saline intrusion is present, this zone moves by approximately 10 km with respect to the position in maximum low water slacks moments, the highest salinity differences oscillate from km 15 to km 30."

The legend of Fig 5 (In the new version is Fig 6) has been corrected as:

"**Figure 7:** Superposition of current velocity (m s^{-1}) time series and Salinity (psu) time series at Bonanza station (4 km). black dots mean maximum and minimum salinity moments selected for MG2 (a) and MG3 (b) oceanographic campaigns. Series of salinity (psu) along the Guadalquivir estuary (km) between real flow and various reductions in freshwater flow for MG2 (c) and MG3 (d). In c and d, the red lines represent experiment (i), the blue lines correspond to Experiment (ii) and the cyan lines are experiment (iii). (b) and (d) are the series of salinities using the real freshwater flow and greater freshwater flows for MG2 and MG3, respectively (Experiment (iv) is represented by the blue line, Experiment (v) is green line and experiment vi is presented by pink lines). The solid lines represent the time of maximum salinity at Bonanza, and the dashed lines represent the time of minimum salinity at Bonanza. Color dots represent the km of maximum differences between each experiment with Experiment (i)."

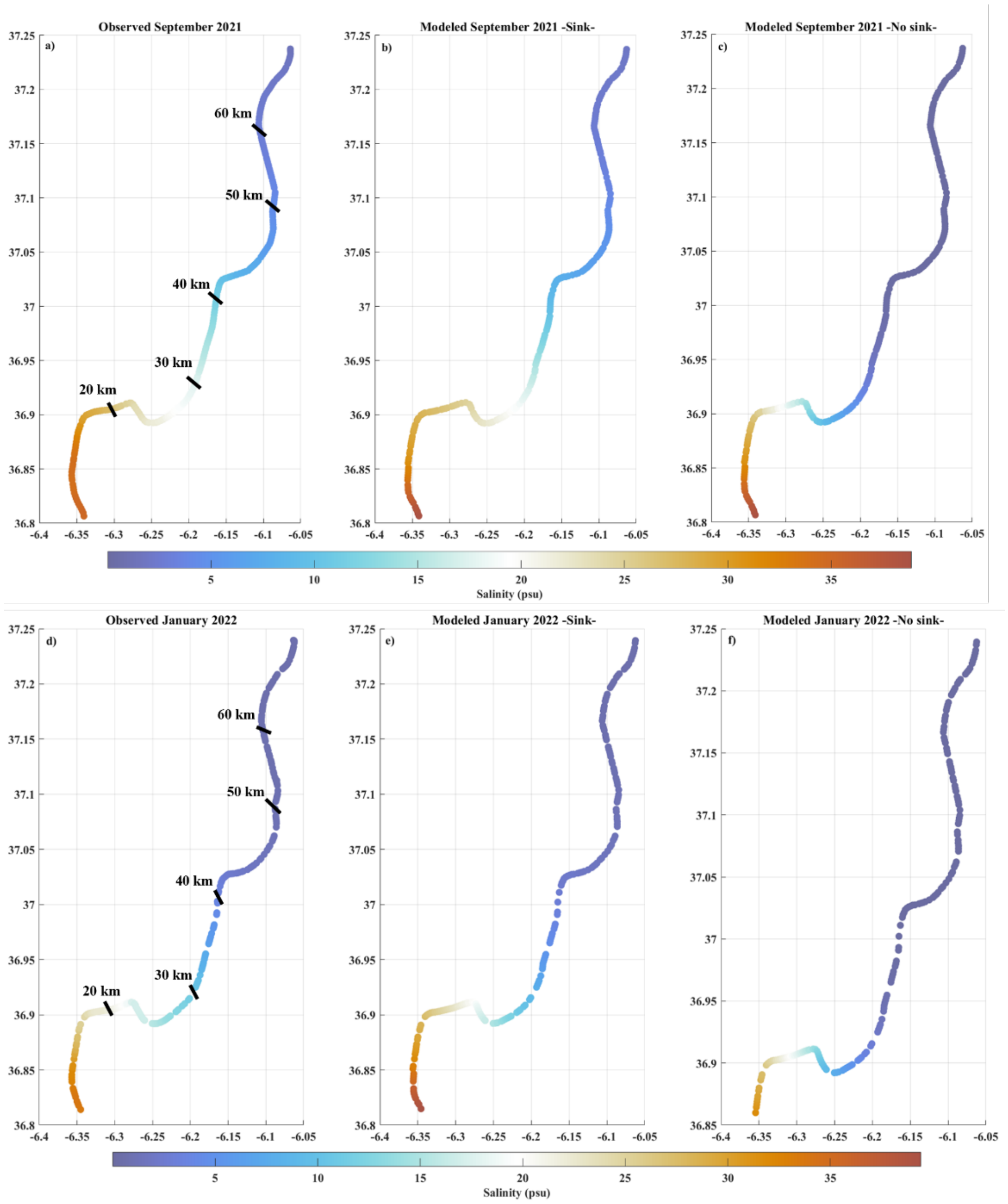
We hope now it is more clear and there is not option to be confused.

7. **The term 'salt wedge intrusion' is not right. It is either salt intrusion or salt wedge, not all together.**

Thank you for comment, we have modified each term following comment 2 (Major comments section)

8. Figure 3, indicate where km 30 , 40, 50 etc. is

Done. Figure 3 has been corrected including your suggestion.



9. Line 323-324 what do you mean ‘a gradual decrease in salinity values upstream can be seen’ . Do you mean gradual decrease during neap tide?

No, the sentence refers to Figure 4. However, it is true that the way the sentence is worded is confusing. We meant to say that if you look at Figure 4a you can see a 1.5 hour lag between tidal height and salinity, and if you look at Figures 4b and 4c you can see a gradual decrease in salinity concentration from the mouth to the head of the estuary (along the channel) . We have added references to the figures to improve the clarity of the text.

“A lag of about 1.5 h was observed between tidal height and salinity profiles (Fig. 5a), which means that the maximum and minimum salinity concentration values coincide with moments just before high and low tide, respectively. Fig. 5b and d, shows a gradual decrease in salinity values upstream.”