<u>Reviewer # 2 Questions and our responses</u>

We thank Reviewer #2 for excellent comments and suggestions, which helped us to improve our paper. In this section, we first list the reviewer's question/comment, and then provide our answer. The questions/comments are in italics, and our response is in bold text.

In this manuscript, an unsteady analytical solution was presented to simulate the spatial-temporal variation of salinity in convergent estuaries and applied to the Humen estuary of the Pearl River Delta. There are a lot of issues which should be addressed.

Major points:

1. This manuscript is about the unsteady state analytical model for salt intrusion, but in the introduction section there is no anything about unsteady state analytical model. Nobody else did the unsteady state analytical model?

At present, there are few studies presenting unsteady state analytical models to analyze the intratidal variation of salinity. Song et al. (2008) have proposed one applicable to laboratory flumes and rectangular canals, in a Chinese journal. We refer to this study in the introduction of the revised version, as below:

"…There are few studies focused on analyzing the intratidal variation of salinity analytically. Song et al. (2008) proposed an unsteady-state model applicable to laboratory flumes and artificial channels where the cross section is assumed to be constant along the channel. Here, an unsteady-state model is developed to predict the intratidal salinity intrusion dynamics in alluvial estuaries where the cross-section area typically converges."

Song, Z. Y., Huang, X. J., Zhang, H. G., Chen, X. Q., and Kong, J.: One–dimensional unsteady analytical solution of salinity intrusion in estuaries, China Ocean Eng., 22, 113–122, 2008.

2. What differences are there between your model and previous models? What are the advantages of your model? Authors should compare your model results with other model results, to prove that your model is better.

The unsteady analytical model developed by Song et al. (2008) can reproduce the salinity process in an idealized estuary with constant depth and constant width. Therefore, Song's model is best applicable to laboratory flumes and artificial channels. However, the convergence of cross-sectional area of estuarine channels is crucial. One innovation of this paper is to make use of the natural topography of alluvial estuaries, where the cross-sectional area development along the channel obeys an exponential function. So, our paper continues on Song's work within the geometrical setting of an alluvial estuary.

3. In the methods section, which are input parameters, and how to determine them? These should be presented clearly.

The input parameters include the tide-averaged salinity at the mouth, the convergence length of cross section *a*, the dispersion coefficient *D*, the tidal

excursion E_0, the damping length of the tidal excursion e, the initial phase φ_0 and the tidal celerity c. We provide two approaches to estimate the calibrated input parameters. In the method section of the revision, we will introduce a way to calculate the tidal velocity υ (i.e. tidal excursion E) and the tidal propagation celerity (c) using the analytical hydrodynamics models by Cai, et al. (2012) and Cai and Savenije (2013). However, without geometry and friction data at the estuary mouth, the analytical model for tidal dynamics cannot be used in this case. Therefore, the input parameters in this study are calibrated using the measurements of salinity. The calibration of the parameters are presented one by one in Section 4.1 in the revised version.

Cai, H., Savenije, H. H. G., and Toffolon, M.: A new analytical framework for assessing the effect of sea-level rise and dredging on tidal damping in estuaries, J. Geophys. Res., 117, C09023, doi:10.1029/2012JC008000, 2012.

Cai, H., and Savenije, H. H. G.: Asymptotic behavior of tidal damping in alluvial estuaries, J. Geophys. Res., 118(11), 6107-6122, https://doi.org/10.1002/2013JC008772, 2013.

4. In the application of the model to the Humen estuary, the first location of measurements (Dahu, figure 1) was set as the mouth of the estuary, and authors only calculated the results between station 1 and station 6 (figure 4). Actually, the real mouth is far downstream from station 1.

The Humen estuary is the largest river outlet in Lingding Bay that connects the South China Sea and the Humen estuary. In this study, we choose the Dahu station (station 1) as the mouth of the estuary because it is usually considered as the bayhead of the Lingding Bay (Liu et al., 2000; Tian, 1986). The Dahu station is the connection point between the Humen estuary and Lingding Bay.

Liu, P., Wen, P., Zhou, Z., and Yu, T.: Analysis of influencing factor on shoal and though development of Lingdingyang Bay at Zhujiang Estuary, Journal of Oceanography in Taiwan Strait, 2000, 19(1), 119-124.

Tian, X.,: A study on turbidity maximum in Lingdingyang Estuary of the Pearl River, Tropic Oceanology, 1986, 2.

5. In figure 2, the cross-sectional area of the Humen estuary was only shown for the reach between 0 km to 60 km. However, the Humen channel has a total length of 128 km (page 7, line 4). I think that the mouth in figure 2 should be the same as that in figure 4. If only part of the topography data was used, the area convergence length you obtained may be not correct. It is an important parameter in the model.

Unfortunately, this is all the cross-section information we have at our disposal. We agree it would be better to use a longer stretch of the channel to estimate convergence length, but at the same time we have no reason to believe the channel geometry would not fit the same function in the part where we have no geometry data.

6. Section 4.1 (Application to the Humen Estuary) is about calibration of model. Authors only discussed the calibration of parameters. The calibration results of model were shown in section 4.2 (model validation). In other words, model calibration and model validation used the same data. Although in figure 4 the results between 29 January and 3 February were shown, the conditions were similar.

We have rewritten Section 4.1 to clarify this in the revised version. The calibrated parameters include tidal excursion *E* and dispersion coefficient *D*. Although each of the calibrated dispersion coefficient from 29 January to 3 February was listed in Table 2, in fact, only the one on 29 January was used in the study. In other words, we use the data on 29 January to calibrate the model parameters, and use the data from 30 January to 3 February to validate the model. We agree it would be interesting to see how the model performs under different conditions. This contribution can be considered a proof of concept. In the revised version, we use two figures to show the results, Figure 4 is the calibrated result and Figure 5 is the validation results, as below:

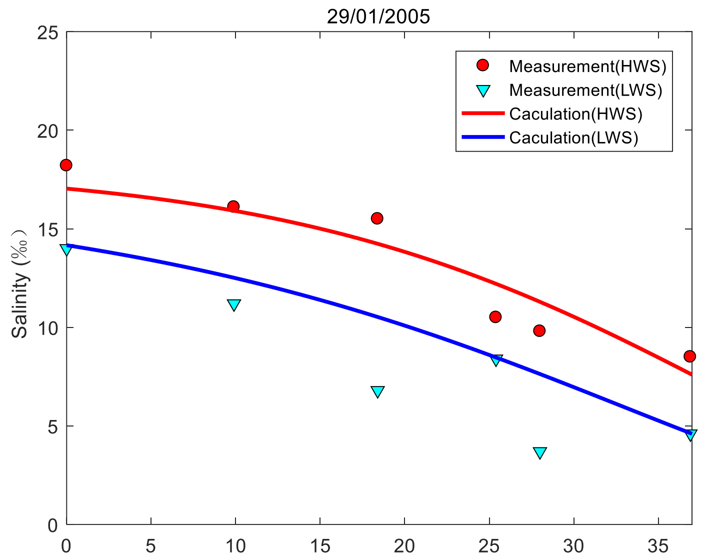

Figure 4: Comparison between calibration result and measured salinity concentration along the river on 29 January, 2005, showing values of measured salinity at high water slack (circle) and low water slack (inverted triangle), and the calibrated salinity curves at high water slack (red curve) and low water slack (blue curve).

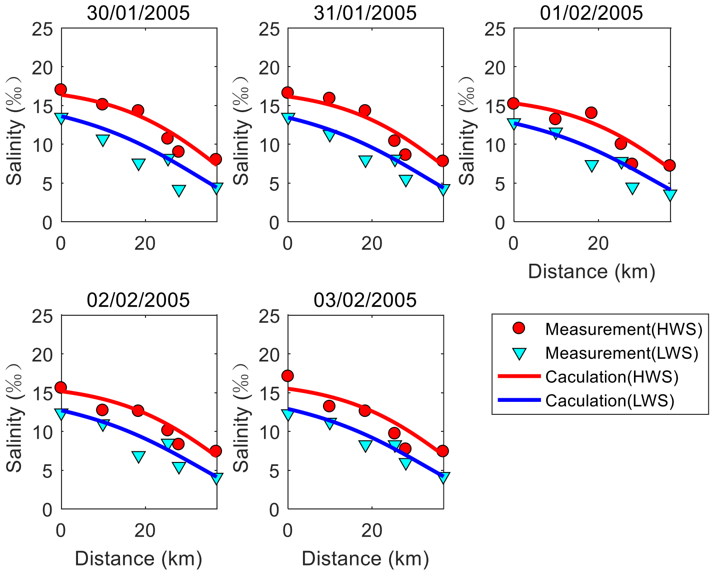

Figure 5: Comparison between validation result and measured salinity concentration along the river from 30 January to 3 February, 2005.

7. Section 6 Conclusions. In this manuscript, the main work is application of the model to the Humen estuary, showing calibration results. The first paragraph is enough. In the second paragraph, part is about results instead of conclusions, and the other part is already in the first paragraph. In addition, "predictive", "predicating", and "predictable" used in conclusions are not proper.

We appreciate the reviewer's suggestion and deleted this part of conclusions in the revised version.

Minor points:

1. Page 1, lines 16-17: "Compared with steady-state solutions, it can directly reflect the influence of the tide and the interaction between the tide and runoff". Salt intrusion is the result of interaction between tide and runoff. The steady-state solution cannot reflect the influence of tide and interaction of tide and runoff? And authors did not compare their solution with steady-state solutions.

We agree that the steady-state solution can reflect tidal influence and interaction of the tidal motion and runoff. We have modified that inaccurate description in the revised version as below:

"…It is derived from a one-dimensional advection-diffusion equation for salinity, adopting a constant mixing coefficient and a single-frequency tidal wave, which can directly reflect the influence of the tidal motion and the interaction between the tide and runoff…"

There are two reasons why we did not compare our solution with other steady models in this paper. Firstly, in this study, we concentrated more on analyzing and discussing the ability of our unsteady model to capture the intratidal variation of the salinity. Secondly, the steady-state solution of our model obtained by

integrating over the tidal period has the same expression as a widely used analytical model defined by Brockway et al. (2006). So, not surprisingly, our model applies well to the estimation of salinity distribution compared to the observations. Moreover, we did the relevant research and investigated the applicability of different steady solutions. Brockway's model has a simple calculation process and provides an accurate distribution of salinity in the downstream estuary (Xu et al., 2015).

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, Estuarine Coastal Shelf Sci., 2006, 66, 1–5.

Xu, Y.W., Zhang, W., Chen, X.H., Zheng, J.H., Chen, X.W., Wu, H.X.: Comparison of Analytical Solutions for Salt Intrusion Applied to the Modaomen Estuary, J. Coastal Res., 2015, 31(3), 735-741.

2. Page 1, line 31 and page 2, line 1: "Hence, the effects of human activities on salt intrusion are of major interest to engineers and scientists". This sentence is not related to the topic of this manuscript. Authors did not do anything about the influence of human activities.

We appreciate the reviewer's suggestion and deleted this sentence in the revised version.

3. Page 3, lines 2-5. The sentences about paper organization are not necessary.

Agreed, we deleted this part of introduction in the revised version.

4. Page 6. What is e in equations 17 and 18?

***e* is the damping length of the tidal excursion. We explain this in the revised version as below:**

"…where $E0$ is the tidal excursion at the mouth (x=0), and e is the damping length of the tidal excursion…"

5. Page 6, line 20. Here the citation of a reference is not necessary. Particularly the reference is from a foreigner. Is a foreigner more familiar with a Chinese estuary?

We appreciate the reviewer's suggestion and deleted it in the revised version.

6. Page 7, line 6. What does the ES mean?

It was a mistake here. It should be "SE" which represents Southeast. We have corrected it in the revised version.

7. Page 7, lines 16-17: "The Humen waterway is well-mixed in the dry seasons (Luo et al., 2010)". The mixing condition can be seen directly from the vertical distribution of salinity, which should be shown in section 3.1 (overview of the study area).

The field survey was carried out by Guangdong Province Hydrology Bureau and the Pearl Hydrology Bureau from the River Conservancy Commission.

Unfortunately, they only provided us the vertical averaged salinity at each measuring location because of the well-mixed condition in Humen estuary. To justify the lack of the vertical salinity data, we add more citations to support the assumption of well-mixed conditions in the revised version, as below:

"…The Humen estuary is well-mixed under normal flow conditions during the dry season (Ou, 2009; Luo et al., 2010). Due to three years of drought, the river discharge decreased by 50 percent during the study period in 2005 compared to a normal year (Liao, Pan, and Dong, 2008). Therefore, there is no doubt that well-mixed conditions prevailed during the calibration and validation…"

Liao, D.Y.; Pan, T.J., and Dong, Y.L., 2008. Characteristics of salt intrusion and its impact analysis in Guangzhou. Environment, S1, 4-5. (In Chinese)

Luo, L., Chen, J., Yang, W., and Wang, D.X, 2010. An intensive saltwater intrusion in the pearl river delta during the winter of 2007–2008, J. Trop. Oceanogr., 6, 22-28. (In Chinese)

Ou, S.Y., 2009. Spatial difference about activity of saline water intrusion in the Pearl River Delta. Scientia Geographica Sinica, 29(1), 89-92. (In Chinese)

8. Page 7, section 3.2 data. What data about the tide was used in this study? In line 12, it is tidal flow. But in line 19, it is tidal level.

The data of tidal flow is needed in our analytical solution, i.e. Eq (11). However, in this study, we used the tidal excursion instead of the tidal velocity, adopting a theoretical relation.

9. The title of section 4.1 can be changed into "Model calibration", corresponding with section 4.2 Model validation.

We appreciate the reviewer's suggestion and changed the title of section 4.1 into "Model calibration" in the revised version.

10. Page 9, lines 18-19. Why did you use the daily maximum and minimum salinity in figure 4?

Because the salinity were measured at hourly intervals. The daily maximum and minimum salinity were used as the approximate HWS and LWS salinity since the exact salinity values at HWS/LWS couldn't be obtained.

11. Page 9, the last paragraph. I did not understand what authors wanted to express except for the first sentence. In the first sentence, the "downstream" is relative to the 40 km reach in figure 4 or the whole channel? It can be seen from figure 4 that the main overestimates occur at station 3 and station 5.

Our study area is the downstream part of Humen estuary, therefore, "downstream" is relative to the whole channel. In Figure 4, we use 72 measured salinity observations at six stations at HWS and LWS to analyze the calculation results. As shown in Figure 4, overestimations occur at stations 2, 3, 4 and 5; 32 of the 72 measured salinity observations are overestimated compared with the

calculation results, while 8 are underestimated.

12. Page 10, line 16: "salinity variation is more symmetrical further away from the study site". What does this sentence mean? It is difficult to understand.

The sentence means: Farther away from the mouth, the calculation of the intertidal variation improves, featuring more symmetry in the tidal cycle.

13. Page 10, lines 29-30. Authors used this sentence to explain the nonperiodic variation of salinity at Machong station in figure 5. It seems that only in the second tidal cycle, the variation is abnormal.

In comparison with the calculation results at the other stations, the model doesn't perform very well in Machong station. This may relate to nonperiodic variation in the velocity signal.

14. Page 16, table 2. All parameters used in the model should be shown.

We appreciate the reviewer's suggestion. All parameters used in the model are shown in Table 3 in the revised version as below:

Table 3 Calibrated values of Parameters

Parameter	Unit	Value
A_0	m^2	37822
a	km	16.7
D	m^2/s	2562
E_0	km	26.7
e	km	30
c	m/s	12
φ_0	rad/s	-0.7

15. Page 17, figure 1.
(1) The Pearl River estuary is too complicated, and Humen is only one of eight branches. The figure caption is map of Humen estuary. But where is Humen? Only six gauging stations can be seen. The Humen estuary should be enlarged and shown clearly.
(2) River names "Beijiang River and Xijiang River" are different from the names "the North river and West river" in the text.
(3) East River and the Shiziyang channel in Page 10, line 23 were not shown in figure 1.

We appreciate the reviewer's suggestion and redraw Figure 1 in the revised version as below:

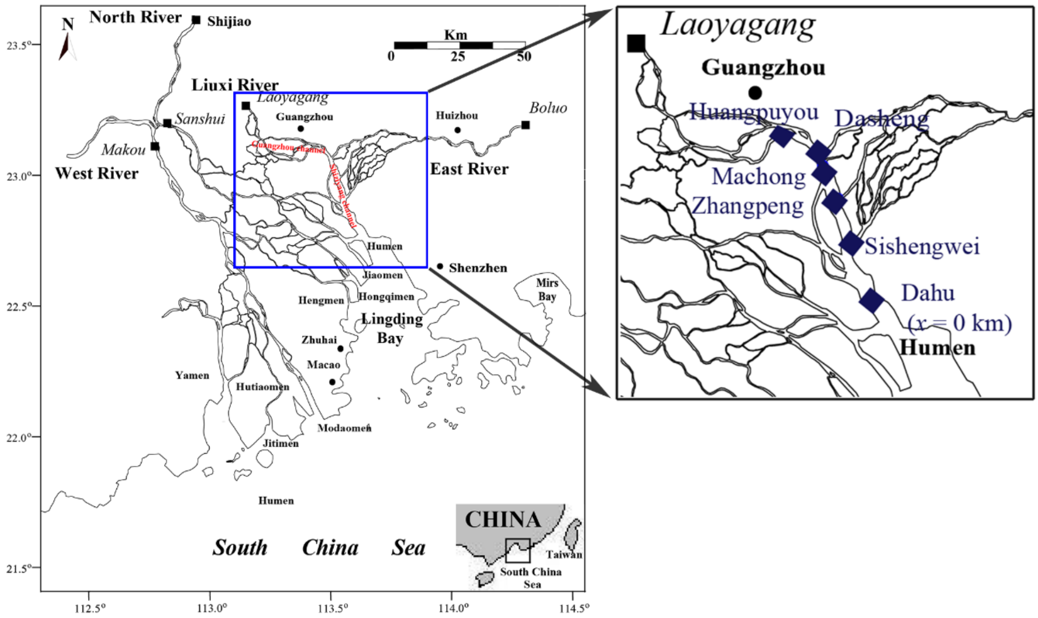

Figure 1: Map of the Humen estuary, showing the gauging stations where salinity concentration was measured during the field survey from 29 January to 3 February, 2005.

16. Page 19, caption of figure 3: "The linear relationship between these quantities predicted by Eq. (12) has been confirmed for all surveys, and the figures here show the linear line fitting results from Jan. 29th to Feb. 3rd". Page 22, caption of figure 6: "The subtidal discharge switches from seaward to landward between Machong and Dasheng stations, which will have an impact on salinity dynamics." These sentences should not be in the figure caption.

We appreciate the reviewer's suggestion and deleted them in the revised version.

17. The legends should be inside or outside figures, instead of covering the curves or words, such as figure 4, figure 6, and figure 7.

We redraw Figures 4, 6 and 7 in the revised version as below:

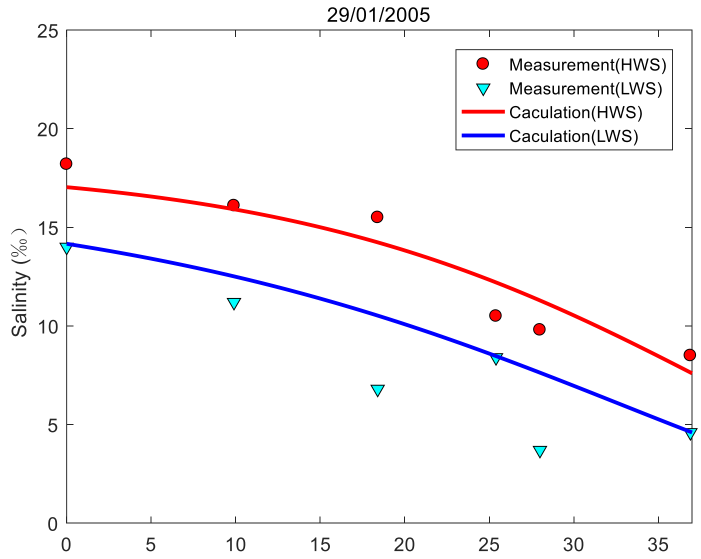

Figure 4: Comparison between calibration result and measured salinity concentration along the river on 29 January, 2005, showing values of measured salinity at high water slack (circle) and low water slack (inverted triangle), and the calibrated salinity curves at high water slack (red curve) and low water slack (blue curve).

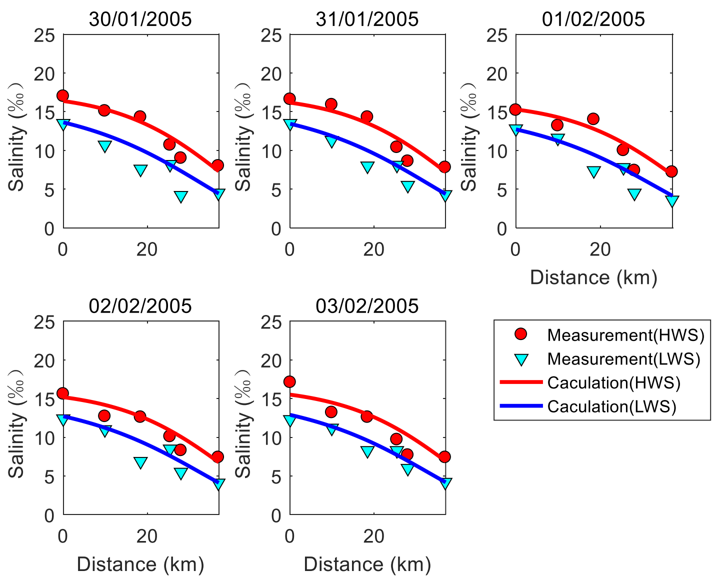

Figure 5: Comparison between validation result and measured salinity concentration along the river from 30 January to 3 February, 2005.

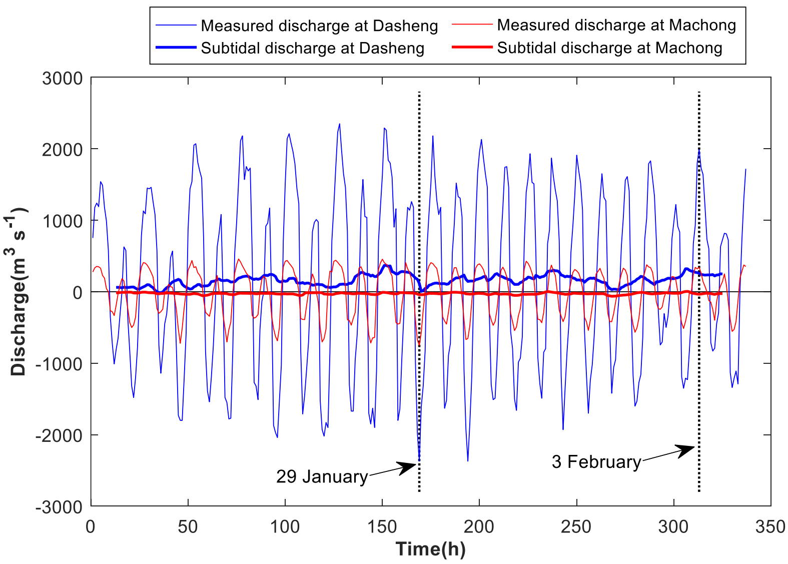

Figure 11: Subtidal discharge measured at Machong station and Dasheng station from 29 January through 3 February. Positive values mean seaward.

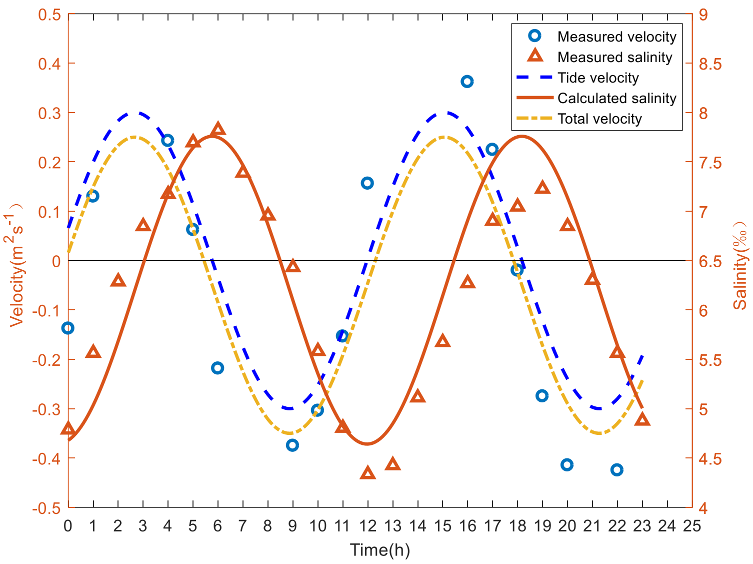

Figure 12: Salinity and tidal flow velocity over a tidal cycle at Huangpuyou station. The measured salinity is represented by triangles and the measured flow velocity is indicated by circles (on 31 January 2005). The dashes line is the calculated tidal velocity while the dash-dotted line is the total velocity of tidal flow and river flow. The red solid curve represents salinity simulated by the unsteady analytical solution, which reproduces the time lag HWS and maximum salinity.

18. Is Humen a waterway or estuary? In some figure and table captions waterway was used, but in others estuary was used. It is the same in the text.

It should be Humen estuary. We have corrected the in the revised version.

19. English writing should be improved. For examples:

(1) Page 7, line 19, "salinity was obtained by using a salimeter". "by" or "using" is

enough.

(2) Page 9 and page 10. "Analysis of " in the titles of section 4.2.1 and 4.2.2 can be deleted. They are not necessary.

(3) Page 12, line 8, "the predicted result obtained by this model". "predicted" or "obtained" is enough.

(4) Page 16, caption of table 2: "Values of the parameters of salt intrusion in Humen estuary". "Values of the" can be deleted, "parameters" is enough.

These are only examples. Authors should check every sentence to make them standard, concise, and fluency

We appreciate the reviewer's suggestion and have made efforts to improve the English grammar in the revised version.