Reponses to comments by Reviewer #1

Dear Reviewer #1,

We are very grateful for your constructive comments and recommendations. Below are our point-by-point responses to each of your comments.

Major concerns:

1. **In this paper, Cai et al. apply an existing analytical model (Cai et al., 2014) to quantify the contributions made by tide, river, and tide-river interaction to the water level slope along the Yangtze estuary. I have two major criticisms: the first one is that the Authors do not present any new model, but only an application of an existing model to a real estuary;**

Our reply: It is true that the proposed analytical model for hydrodynamics has been detailed in Cai et al. (2014). However, the current work represents a further development of the analytical model to understand the mechanism of backwater effect due to tide-river interaction and its resulted mean water level profile in estuaries with substantial fresh water discharge (taking the Yangtze estuary as an example), which is not completely understood yet. For the first time, we used a fully analytical approach to quantify the contributions made by different components (tide, river, and tide-river interaction) to the residual water level. The method is subsequently used to estimate the frequency of extreme high water along the estuary, which is particularly useful for water management and flood control.

We realise that we have not clearly spelled out the innovation of our paper, which is not just an application of a model to a case study, but an analysis that provides new analytical tools to assess the influence of river discharge on water levels in estuaries. In particular, the equations (16)—(18) are new to the analytical method and have not been published before (see also Figure 9 in the manuscript).

2. **the second one concerns the method itself. I think the Author should better state in the Introduction and also in the Discussion section what's the advantage to employ a simplified analytical approach to study the hydrodynamics in an estuary, when in literature, several numerical models, solving the problem in a complete way (even incorporating the morhodynamics), already exist. Usually, simplified analytical approaches have the advantage to reduce computational times compared with numerical models, hence they can be powerful when performing very long term simulations, but this does not seem to be the case of the present investigations.**

Our reply: We agree with the comments by Reviewer and shall include new paragraphs in both Introduction and Conclusions parts to clarify the advantage of using a simplified analytical model as compared to numerical models.

In the Introduction part, we will include the following sentences at the end of third paragraph:
"The proposed method is simple and only requires a minimum amount of data. More importantly, the analytical method provides direct insight into the dominant processes that determine river-tide interaction. As a result, it allows us to better understand how tidal propagation in estuaries is affected by fresh water discharge."

In the Conclusions part, we shall clarify the advantage of analytical model by supplementing the following paragraph:
"Despite the fact that the analytical model requires a certain number of assumptions and thus the results are not as accurate as those of a fully nonlinear numerical model, there are some important advantages in using a simplified analytical approach, as compared to numerical models. First of all, the analytical models are completely transparent, allowing direct assessment of the influence of individual variables and parameters on the resulting mean water level. In addition, analytical methods are fast and efficient so that wide ranges of input parameters can be considered. Furthermore, they are

more appropriate in data-poor (or ungauged) estuaries since only a minimum amount of (geometrical) data is required. Finally, they provide direct insight into cause-effect relations, which is not as straightforward in numerical models."

Minor observations:

1. Page 8384 Lines from 12-to 15. Is this result and, in particular, the quantification of the effect (1.25

Our reply: Yes. As a result of the density influence, there exists a density-induced pressure in landward direction, which is counteracted by a residual water level Δh amounting to 1.25% of the estuary depth h over the salt intrusion length (see P37 Savenije, 2005). This phenomenon has to do with the balance between the hydrostatic forces at the downstream and upstream ends of the salt intrusion length, leading to

$$\frac{1}{2}(\rho+\Delta\rho)gh^2=\frac{1}{2}\rho g(h+\Delta h)^2,$$

where ρ is the density of river water, $\Delta\rho$ is the density difference between ocean and river water, g is the acceleration due to gravity. The above equation can be simplified as (neglecting the second-order term containing Δh^2)

$$\Delta h\approx\frac{\Delta\rho}{2\rho}h=\frac{(1025-1000)}{2000}h=0.0125h.$$

2. Page 8386 Line 9. Add references.

Our reply: Indeed, we shall include some references. The sentence will be updated as follows:
In a tidal river, we usually observe that the tidally averaged water level rises in landward direction (e.g., Kukulka and Jay, 2003; Buschman et al., 2009; Sassi and Hoitink, 2013; Guo et al., 2015).

3. Page 8386 Lines from 14 to 23. Too long sentence. Split line 20, as follows: ': : :). Note that in Table 1 η indicates tidal amplitude, : : :'

Our reply: Many thanks for your suggestion. Corrected as suggested.

4. From line 15 of page 8387 to line 1 of page 8389. Too long sentence!

Our reply: We shall properly adjust the expressions to avoid a too long sentence.

5. Page 8390 line 14. Add parenthesis before and after equation number 19.

Our reply: Corrected as suggested.

6. Page 8391 lines from 5 to 9. I'm not sure the approach is always valid. Is it still valid also in the case of strong longitudinal gradients of the bottom and of the flow field? Please explain better.

Our reply: Yes, the proposed multi-reach approach is valid for the case with strong variation of water depth (or bed elevation). We shall clearly clarify this point in the revised paper.

In order to correctly reproduce the main tidal hydrodynamics along the entire estuary axis, we adopt a multi-reach approach by subdividing the entire estuary into multiple reaches to account for the longitudinal variations of the cross-sections (such as water depth and bottom friction). For given amplification number δ and tidal amplitude η_0 at the seaward boundary of each reach, a tidal amplitude η_1 at a distance Δx (e.g., 1 km) upstream can be calculated by a simple explicit integration of the amplification number:

$$\eta_1=\eta_0+\frac{\mathrm{d}\eta}{\mathrm{d}x}\Delta x=\eta_0+\frac{\eta_0\omega\delta}{c_0}\Delta x.$$

Based on the computed η_1 and the geometric feature (e.g., depth) of the next reach, the main tidal dynamics δ, μ, λ, and ε can be obtained by solving the set of equations (3)—(6). Such a process can be repeated by moving the origin of axis for each reach, leading to the solutions for the entire estuary. In principle, the proposed method is valid for an arbitrary bed profile, even with strong longitudinal gradient of bed elevation.

7. **Page 8395 line 2. Rephrase as follows: ': : : estuary where the influence...'**

Our reply: Corrected as suggested.

8. **Figure 0. Add a figure reporting also the longitudinal profile of the estuary with the notation used in the article.**

Our reply: In the revised paper, we shall include the following figure (Figure R1) as Figure 1 to illustrate the longitudinal profile of the estuary as well as the relationship between different water levels.

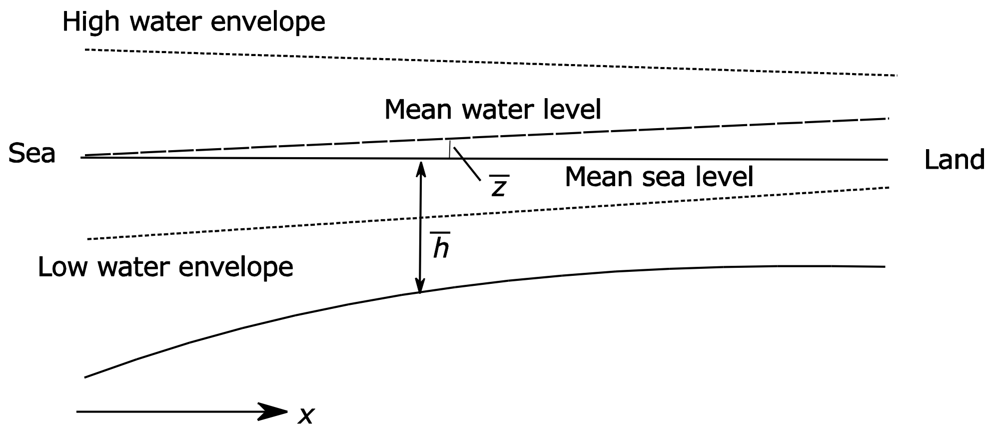

Figure R1. Sketch of the water levels in a tidal river.

9. **Figure 5. Is the mean depth of the estuary the same in the different seasons? Is the plotted value an annual average? Please specify better.**

Our reply: Generally, the tidally averaged depth profile along the estuary axis varies from cycle to cycle because the residual water level (or mean water level), due to nonlinear frictional effects, depends on the imposed fresh water discharge. Thus, the tidally averaged depth would be larger in the flood season than in the dry season in the Yangtze estuary. In fact, the depth presented in Figure 5 is the averaged depth relative to mean sea level (see also Figure R1 above). As described in Section 2.3 in the manuscript, the correct residual water level (and hence tidally averaged depth) is reproduced by an iterative procedure. We shall clarify this point in the revised paper.

10. **Figure 8. Because of the different scales used to plot Q, it is not easy to appreciate when tide or river discharge dominates.**

Our reply: You are right! We shall use the same scale for the plotting (see the revised Figure R2 below).

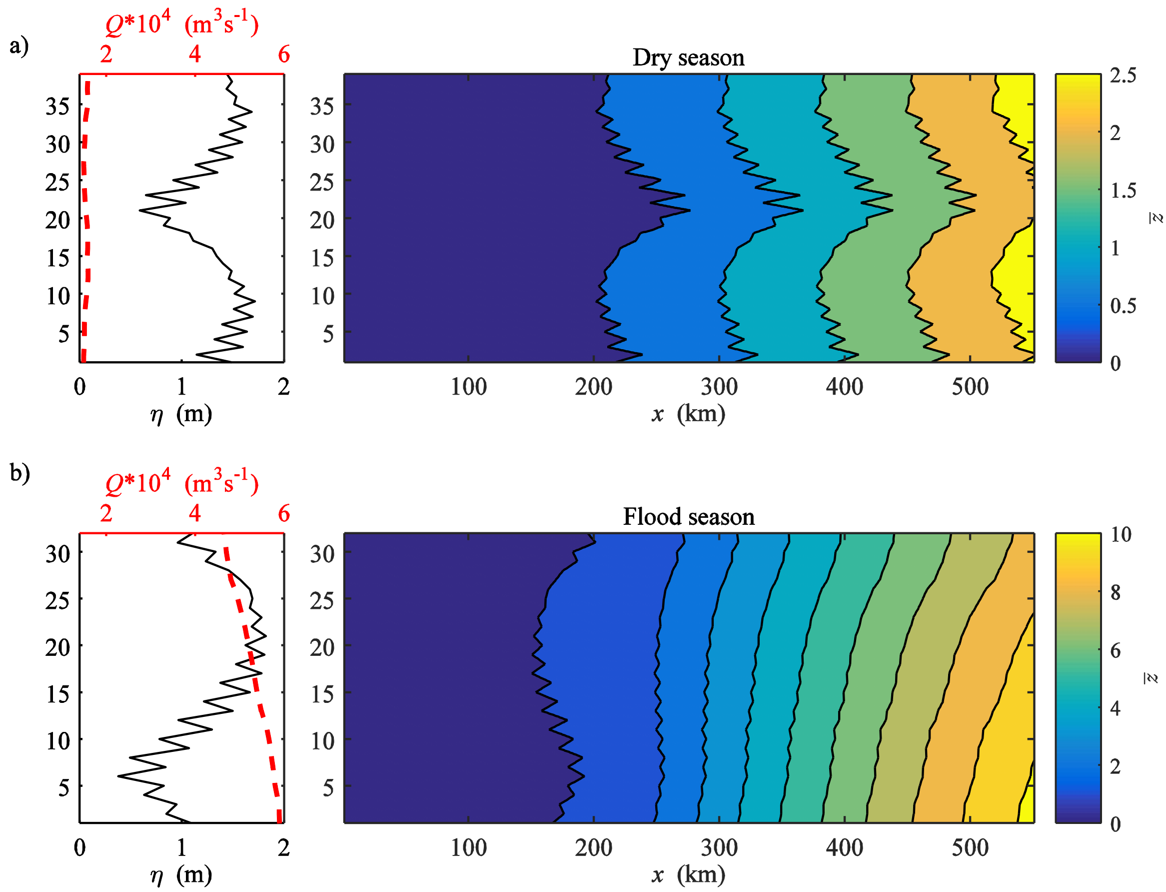

Figure R2. Longitudinal variation of the mean water level along the Yangtze estuary axis as a function of time for the dry season (a) and flood season (b). The left panel shows the corresponding observations of tidal amplitude at Hengsha station and fresh water discharge at Datong station.

11. Figure 11. Add also a line for the bottom elevation, in order to better appreciate what's the local value of the mean flow depth.

Our reply: Indeed, we shall include the bed elevation in the Figure 11 (see below Figure R3).

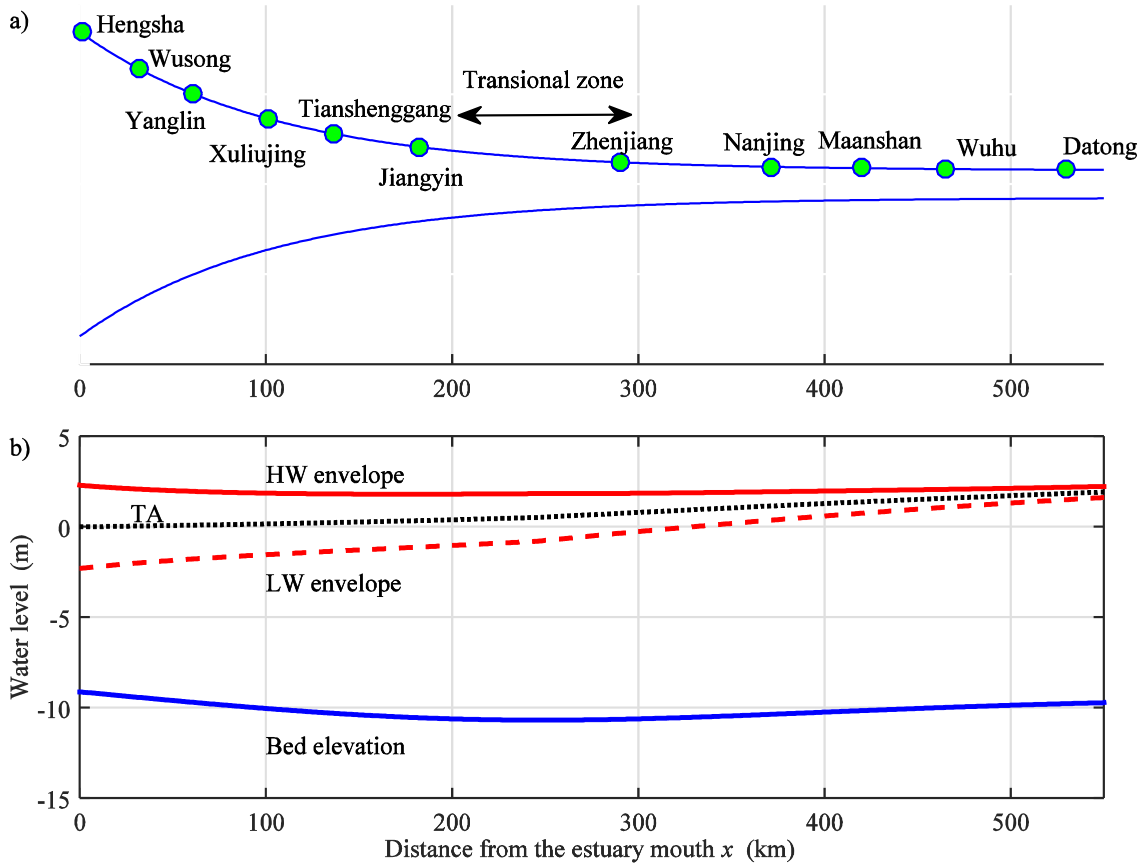

Figure R3. Shape of the Yangtze estuary (a) and the longitudinal computation of the high water (HW) and low water (LW) envelopes, together with the bed elevation along the Yangtze estuary (b) for given values of η_0 =2.3 m, Q = 10 000 m^{3}s^{-1}. The TA curve marks tidal average values.

References

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