Response letter to Reviewer#1

We thank Reviewer#1 for the careful consideration of our work. We agree with his/her constructive and thoughtful comments and suggestions, which led to a much improved and complete manuscript. In this response letter, we have replied (in blue) to all the comments formulated by the Reviewer (in black).

Comments:

This manuscript discusses fortnightly (~14.8 day) variations in surface elevation along an estuary, as recorded in measurements and found in a model. The focus is on tidal forcing with neglect of river discharge and atmospheric forcing. The introduction and discussion indicate that these elevation variations can be significant in several contexts. However, given considerable existing literature, some with river discharge, this is a simpler scenario and the results are in general unsurprising. Good agreement between model and observations is obtained. The degree of novelty can be questioned and one would expect more discussion of the relation with previous results including river discharge (which I guess has varied magnitude relative to the tidal prism in the various contexts treated in the literature).

Our reply: We very much appreciate all the comments raised by the reviewer. In the revised manuscript, we shall completely address all the comments. Specifically, we shall highlight the novelty of this manuscript in the introduction:

"Overall, this research proposes, for the first time, an analytical tool for assessing the impacts of geometric changes (such as the mean depth or length of the estuary) on fortnightly water level variations in tide-dominated estuaries with negligible river discharge. The results shed new light on how fortnightly dynamics in water levels is generated due to imposed tidal forcing at the mouth and tidal wave reflection from the head of the estuary. Through estimates of the MWL along the estuary, the approach is specifically helpful for sustainable water resources management of ecosystems, especially in macrotidal estuaries."

1. Non-dimensional parameters are introduced but not sufficiently exploited in my opinion. There is a focus on values pertaining to the observed Guadiana estuary. What about an estuary near resonance with M_2?

Our reply: Indeed, the proposed analytical model is mainly used to better understand the fortnightly water level dynamics along the Guadiana, an example of semi-arid estuaries which have been poorly documented so far. Given the fact that we have reproduced the tidal hydrodynamics (including resonance behavior) in the Guadiana estuary by means of an analytical model in our previous work (Garel and Cai, 2018), here in this study, we did not discuss more details with regard to resonance behavior.

2. I am not convinced by the (repetitive rather than justified) attribution of the behavior to friction rather than non-linearity in the advection terms. This must depend on their relative magnitude which depend on the length and depth of the estuary. I question the analysis in 4.2. Non-linear effects on M_2 usually show in M_4 as a result of advection and M_6 as a result of quadratic friction. However, here the quarter-diurnal species (mainly M_4) are attributed mainly to friction and sixth-diurnal species are not discussed.

Our reply: We agree with the reviewer's comments on the generations of the even harmonics (e.g., M_4) and odd harmonics (e.g., M_6). Indeed, the generation of quarter-diurnal species is mainly attributed to the nonlinear continuity term, the convective acceleration term and the quadratic friction term, while the generation of sixth-diurnal species is primarily induced by the quadratic friction term (Parker, 1991). In the revised manuscript, we shall modify the corresponding sentence as: *"Typically, the growth of these constituents in the upstream direction indicates increasing distortion of the tidal wave due to the combined effects from non-linear continuity term, convective acceleration term and quadratic friction in both mass and momentum equations (Parker, 1991)"*.

In addition, we shall explicitly mention that:
"*Note that the sixth-diurnal species were not analysed since their magnitudes are relatively small when compared with other components (see Garel and Cai, 2018).*"

3. In general the English is good and understandable, despite occasional strange usage which should be picked up in copy-editing. However

- There is frequent reference to "equinoctial" which is incorrect and obscures the intended meaning, e.g. lines 199, 239, 240, 241, 244, 596. Omit and say precisely the time referred to.

Our reply: We thanks the reviewer to point this out. In the revised manuscript, we shall discard "equinoctial tides". The manuscript now refers to the largest and lowest tides occurring during the study period, which will be explicitly mentioned in section 3.1.1.: *"The largest spring and lowest neap tides were on 31 August 2015 and 24 August 2015, with tidal ranges of 3.3 m and 1.2 m, respectively."*

- "spring" and "neap" should be used as adjectives e.g. "spring tide(s)" or perhaps as plurals e.g. "springs". Do not use "spring" alone; this is a season of the year. Typos etc.

Our reply: We agree with this comment. In the revised manuscript, we shall modify the expressions concerning "spring" and "neap".

4.

- Lines 9, 49. The direction of increase should be stated.

Our reply: You are right! In the revised manuscript, we shall modify the sentences as: *"Observations indicate that the fortnightly fluctuations in mean amplitude of water level increase in the upstream direction along the lower half of a tide-dominated estuary (the Guadiana) with negligible river discharge but remain constant upstream."*

"At settings with extended intertidal areas, the lateral spreading of the flood tidal wave produces additional frictional asymmetries between spring and neap tides that may also contribute to the increase of the fortnightly tide amplitude in the upstream direction (Friedrichs and Aubrey, 1988)."

- Line 34. "metric order" should be "of order 1 m"?

Our reply: Corrected as suggested.

- Equation (1) and line 77. There should be a reference for this form of friction, especially the depth-dependence.

Our reply: In the revised manuscript, we shall explicitly include the reference "Savenije, 2012", especially for the depth-dependence in the friction term.

- Line 83. The relative magnitude of the two terms on RHS(2) is independent of |U| so the relevance of Froude number is unclear.

Our reply: Actually, more details with regard to the relevance of Froude number can be found in Cai et al. (2019):

"Note that the contribution from advective acceleration to the residual water level slope

$$\frac{\partial \overline{Z_{adv}}}{\partial x} = -\frac{1}{2g}\frac{\partial \overline{U^2}}{\partial x} \tag{1.1}$$

can be easily integrated to

$$\overline{Z_{adv}} = -\frac{1}{2g}\left(\overline{U^2} - \overline{U_0^2}\right) = -\frac{1}{2}\overline{Fr_0}\left(\frac{\overline{U^2}}{\overline{U_0^2}} - 1\right)\overline{h_0} \tag{1.2}$$

where the subscript 0 indicates the values at the estuary mouth. Here the Froude number is introduced, $\overline{Fr^2} = \overline{U^2}/\left(g\overline{h}\right)$, which is computed with the averaged variables. In this case, the correction is local (not cumulative) and proportional to the flow depth through a coefficient that is negligible as long as the velocity does not change significantly, and Fr is small, as is common in most tidal flows."

- Line 129. "Equinoctial" can be omitted: not strictly true and made redundant by the other information given.

Our reply: We agree with this comment. In the revised manuscript, we shall remove "Equinoctial tides".

- Line 138. Why should a diurnal tide induce "jagged" fluctuations? Specify their time scale and that of the smoothing.

Our reply: The jagged fluctuations in tidal range are induced by diurnal inequalities of the (semi-diurnal) tide which produce small differences in the height of two successive tides (see figure A below). In the revised manuscript, we shall explicitly mention that: *"The resulting amplitudes were smoothed using a 6-point moving average to discard jagged fluctuations induced by (small) diurnal inequalities of the astronomical tide."*

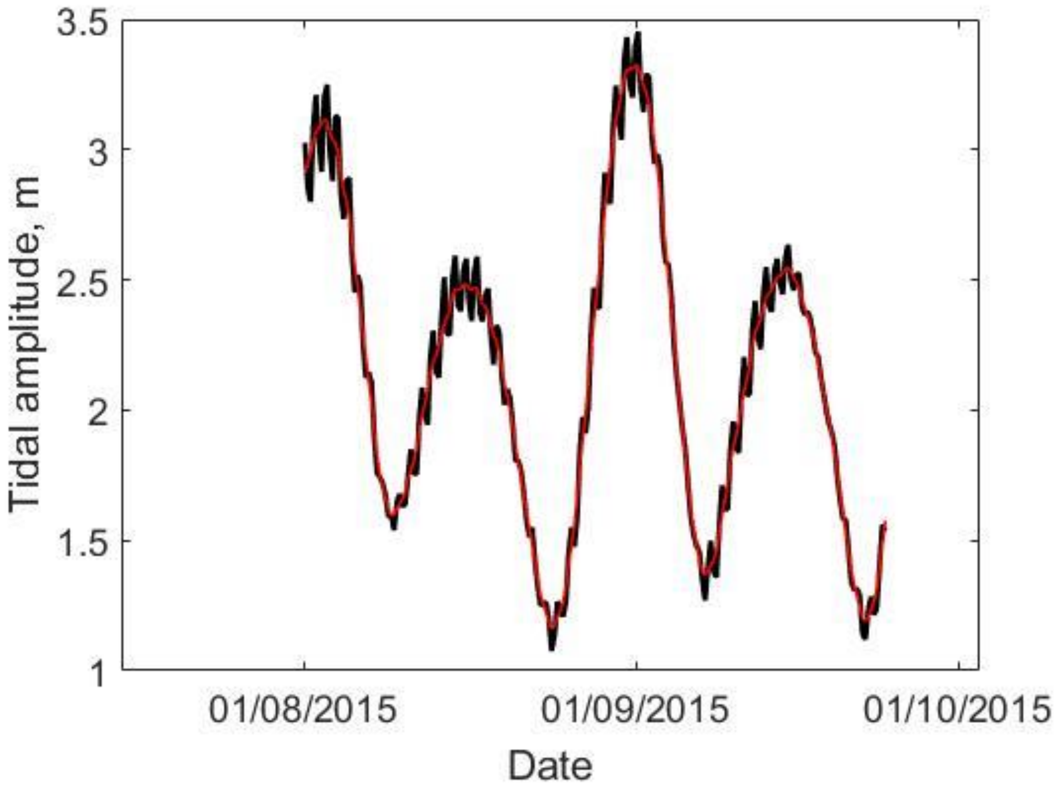

Figure A. Tidal amplitude (m) at the estuary mouth (St0): non filtered data are in black, smoothed data are in red.

- Lines 139-141. If another scientist were to check this work, they would need more specification of the CWT. Also line 187 "using the equations developed by." is too vague. Either they should be repeated or at least equation numbers in the cited papers should be specified.

Our reply: We agree with the reviewer's comments. In the revised manuscript, we shall provide more details with regard to these two methods:

"The basic principles of CWT analyses are described in Jay and Flinchem (1997; see Eqs. 1-3 in their manuscript)."

"The dependent parameters defined in Table 1 can be calculated using the equations developed by Toffolon and Savenije (2011; see also Cai et al., 2016 and Eqs. 6-20 in Garel and Cai, 2018) for both infinite and semi-closed channels."

■ Line 190. "Continuity" of volume flux? Surface elevation? Anything else?

Our reply: In the revised manuscript, we shall explicitly mention that:

"The solutions were then obtained by solving a set of linear equations, with internal boundary conditions at the junction of the sub-reaches satisfying the continuity conditions for both water level and discharge."

■ Line 202. This sentence is unclear. Which period shows the greatest variations? "equinoctial" occurs at the very end of the record. Likewise, lines 212-213.

Our reply: In the revised manuscript, we shall clarify that:

"The greatest water level variations of Z_f (about 20 cm in range) correspond to the largest changes in tidal height, observed between the 24 and 31 August 2015 (see Fig. 2b)."

"For instance, the largest range of Zs variations at St3-6 occurred during the spring and neap tides on the 24-31 August 2015."

■ Lines 245-246. This sentence seems tautological; what exactly is being compared with what?

Our reply: In the revised manuscript, we shall remove this sentence since we used the same data set.

■ Lines 273-275. This is not correctly expressed. (8) relates K to Cd but (9) is an independent value for Cd, presumably coming from Souls by (1997).

Our reply: Here the main purpose of adopting Eqs. (8) and (9) is to justify the calibrated Manning-Strickler friction coefficient.

■ Line 337. "opposed to observations" begs discussion which I don't see.

Our reply: We shall clarify the meaning of this sentence:

"Compared to the IF case, these dynamics should enhance the MWL slope at springs, and thus the MSf amplitude at the upper reach, opposed to observations (see Fig. 2)."

■ Line 350. 15° is about 31 minutes for M2.

Our reply: Corrected as suggested.

■ Line 355. This is section 5.3!

Our reply: Corrected as suggested.

■ Figures 7, 8. It is better practice to include zero on the amplitude scale.

Our reply: Many thanks for the suggestions. In the revised manuscript, we shall modify the Figure 7a-c and Figure 8a.

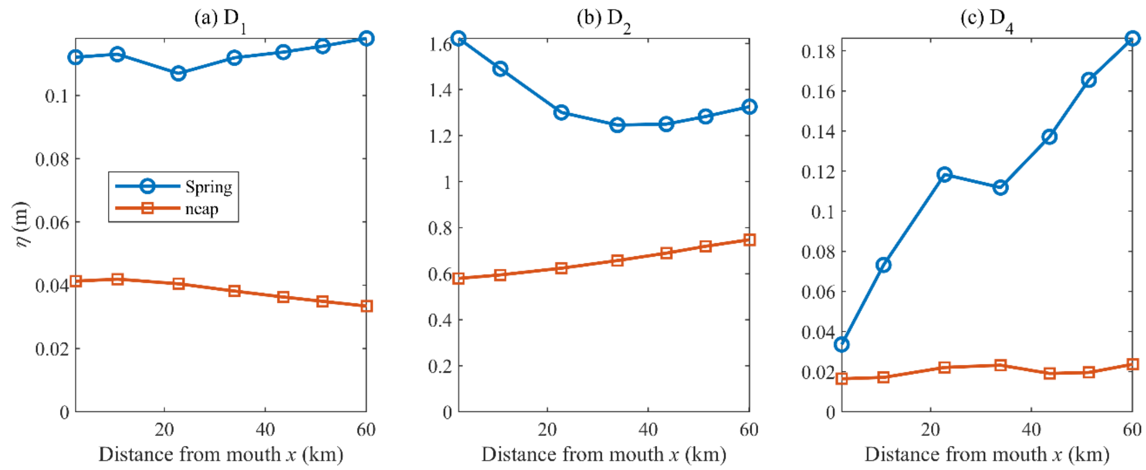

Figure 7: Amplitude (η, m) of tidal species (a) diurnal D_1, (b) semi-diurnal D_2 and (c)quarter-diurnal D_4 along the channel during the largest spring (blue line, 31 August 2015) and lowest neap (red line, 24 August 2015) tides.

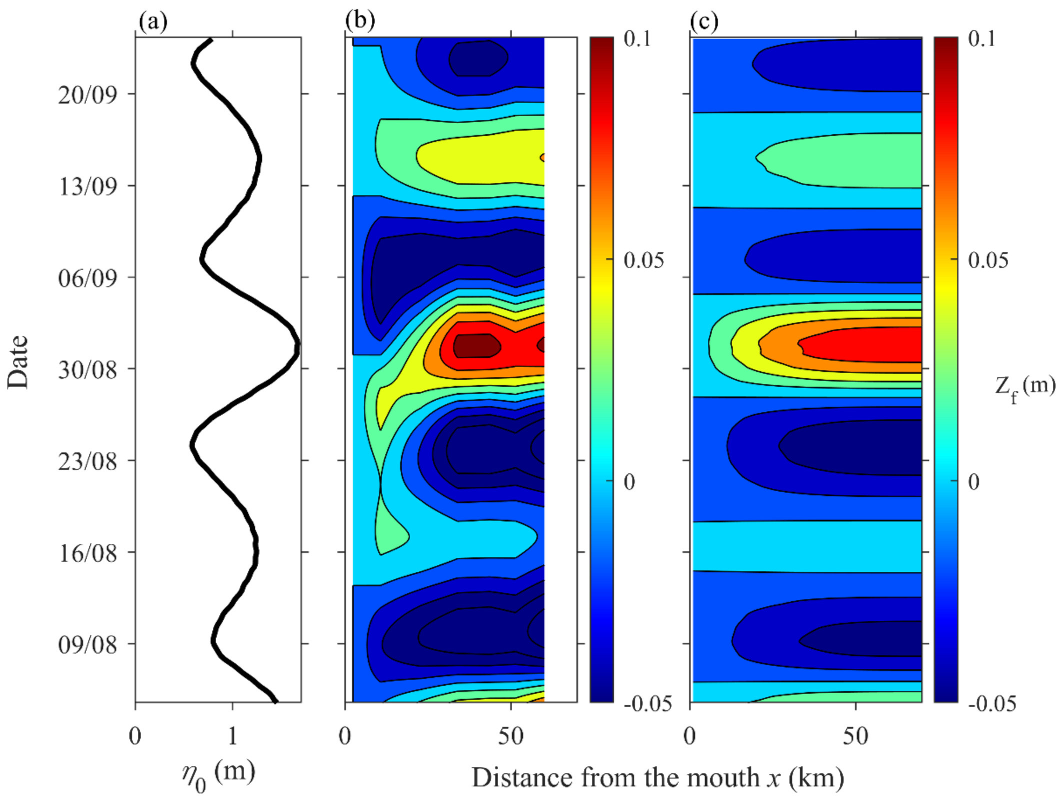

Figure 8: (a) Tidal amplitude at the mouth (η_0, m), (b) observed (Z_f) and (c) simulated (Zm) fortnightly water level variations along the Guadiana estuary.

- Figure 8. The scales for distance from the mouth differ between (b) and (c) and do not include zero.

Our reply: In the revised manuscript, we shall modify the Figure 8:

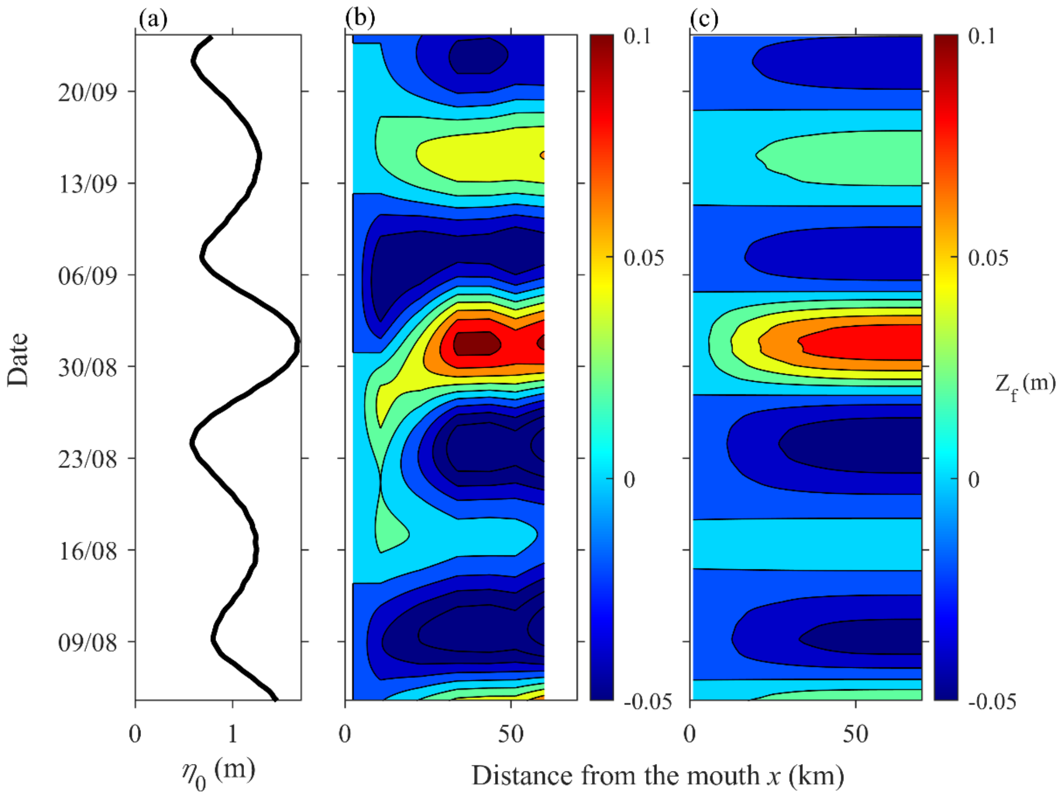

Figure 8: (a) Tidal amplitude at the mouth (η_0, m), (b) observed (Z_f) and (c) simulated (Zm) fortnightly water level variations along the Guadiana estuary.

- Table 1 expressions for damping numbers: if dη/dx and dv/dx are factors then they need to appear without other symbols interspersed.

Our reply: We shall modify the expressions of Damping /amplification number for water level and Damping/amplification number for velocity in Table 1:

"Damping /amplification number for water level":

$$\delta_A = \frac{c_0}{\eta\omega}\frac{\mathrm{d}\eta}{\mathrm{d}x}$$

"Damping/amplification number for velocity":

$$\delta_V = \frac{c_0}{\upsilon\omega}\frac{\mathrm{d}\upsilon}{\mathrm{d}x}$$

References:

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