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Earth System Dynamics Discussions

Interactive comment on "Maximum power of saline and fresh water mixing in estuaries" *by* Zhilin Zhang and Hubert Savenije

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We would like to thank referee #2 for the discussion.

#1 Relation to previous work. I think the manuscript would benefit if the relationship to the authors' earlier work is more clearly described and discussed. This concerns the introduction and the discussion/conclusion. It would really help the reader to understand if the previous work contained errors or whether it was an approximation? I find the current description about the previous work was limited by using an isolated systems' view. This is difficult to understand for a reader that is not completely familiar with the earlier work, so this needs a more detailed description and explanation.

Reply: We shall add a more detailed description of the deficiencies in the earlier work

and how this paper carries the concept of maximum power further. The following additional description shall be added at the end of Page 1: 'In this research, the maximum power concept for estuarine mixing is further elaborated. The equation derived earlier in Zhang and Savenije (2018) appeared to have an analytical solution of a straight line for the salinity distribution. With hindsight this is reasonable: In the center region, where the salinity gradient is at its maximum, dominated by density-driven mixing, the salinity decreases linearly in the upstream direction (Hansen and Rattray, 1965). It can be seen as a first order solution. However, this approximate solution was not fully satisfactory for simulating the salinity distribution. When choosing the boundary conditions at the correct system boundaries, the derivation appears to work better.'

#2 Terminology. In the manuscript, the term "moment" is used. Do the authors mean momentum? Angular momentum? Torque? This is not clear to me (I think you mean torque), so I think it would be helpful to briefly describe/clarify it at the beginning.

Reply: It is indeed the torque. '(torque)' has been added in Line 13, Page 2 after 'an angular moment'.

Minor comments: -Abstract: I found it not so easy in the abstract to distinguish between background knowledge and the contribution by this paper. A sentence somewhere with "Here we show" or similar would help to clarify this distinction.

Reply: 'Accordingly', in Line 9, Page 1, has been changed to 'In this research'. Then the following content is the outcome of the research.

- Page 1, Line 18: What is a "working line"?

Reply: Working line is the line of action, which is a geometric representation of how the force is applied. It is the line through the point at which the force is applied in the same direction as the vector force. 'working lines' in the manuscript has been changed into 'lines of action' in this article.

-Page 2, Line 13: What do you mean by "accelerating energy"? And is Nfric not the friction force, rather than energy dissipation, which should be the product of Nfric and the velocity?

Reply: Accelerating energy is the energy source from fresh water discharge. N_fric is the energy dissipation due to friction F_fric.

-Page 2, Line 15: I would clarify it here that you write an angular momentum balance here.

Reply: It is a moment balance equation, which has a dimension of [MLˆ2Tˆ{-2}].

-Page 4, Line 4: I am not an expert in estuaries. Is the one-dimensional advection-dispersion equation standard knowledge? If so, it would be useful to add a standard reference here.

Reply: This equation comes from the combination of water balance equation and salt balance equation, which is well described by Savenije (2005, 2012). The reference has been added.

- Page 6: In the evaluation section, I found that I missed some information. Where does the data come from? Also, an overview, like a table, of the different estuaries and where they are located would be helpful.

Reply: In Line 15, Page 6, 'The general geometry and measurements follow the database from Savenije (2015), Gisen (2015), and Zhang and Savenije (2017)'. In addition, numbers are the labels of estuaries in Table 1. Two columns name the estuaries and locations have been added in Table 1 in Page 25-26.

- Page 6, Line 8: "paper"? Do you mean a semi-logarithmic plot?

Reply: It has been edited.

- Page 6, Line 13: I would it helpful to know more about the Van der Burgh method so I can understand better what is being compared. Specifically, what are the main differences of the VDB method compared to maximum power? This does not need to

be extensive, but a brief summary of how the VDB method works would be helpful. At this point, the parameter of the Van der Burgh method, K, should also be introduced and described. Also, how does K relate to the parameter C3? They are compared in Table 1, but at present, I do not know what this comparison means. Are they supposed to be the same?

Reply: The Van der Burgh method is a well-performing empirical model to describe the salinity intrusion in estuaries, which considers all the mixing mechanisms mainly including the gravitational circulation and tidal effects. Its application requires two parameters to be calibrated (the empirical Van der Burgh coefficient K and the dispersion coefficient at the boundary condition D_0). The maximum power method, however, considers only the gravitational circulation due to freshwater discharge, which has only one parameter D_g_0 to calibrate. The dispersion distribution D(x) obtained by the maximum power method (based on gravitation mixing only) must be smaller than that of the Van der Burgh method, which provides an additional constraint on the Van der Burgh method. According to our research, K is primarily connected to the estuarine geometry and to a lesser extent to the ratio of the fresh and saline water flows into the estuary. In addition, C_3 has the same value for almost all the estuaries. In Table 1, we merely present the values and we do not compare K and C_3. The following paragraph has been added at the end of the Introduction Section: 'The Van der Burgh (VDB) method is a well-documented approach to solve the salinity intrusion in estuaries (Savenije, 2005, 2012), which takes account of all mixing mechanisms, including the density-driven gravitational circulation and tide-driven mechanisms. For the application of this method, there are two parameters that need to be calibrated, the empirical Van der Burgh coefficient K and the dispersion coefficient at the downstream boundary D_0. This method has performed surprisingly well around the world and has been as the benchmark model for the maximum power model in this research.'

- Page 6, Line 16: The abbreviation MP has not been defined.

Reply:'MP' has been introduced in Lin 14, Page 3.

- Page 6, Line 17: The reference to the Table is broken.

Reply: It has been edited.

- Page 6, Line 37: “too saline to use” - to use for what?

Reply: Too saline for domestic use.

- Page 8, Lines 8-10. As mentioned above, I think there is more that can be learned here by comparing this work to the previous work of the authors. At the moment, this is rather short. I think the authors miss an opportunity here to contrast this approach to the previous one. This should help to identify what one can learn in terms of system setup when applying optimality approaches. I think such a more extended discussion would be very suitable to the context of the special issue on optimality principles.

Reply: Indeed, it is significant to refer to previous work. The last paragraph of the manuscript in Page 8 has been added: ‘This study is a further development of the paper by Zhang and Savenije (2018), which also considered gravitational circulation based on the maximum power concept, but using a different system boundary. The approach followed in this paper uses a broader system boundary and found a solution that combines well with the empirical Van der Burgh method, providing an additional constraint for its calibration. Because the total mixing of the Van der Burgh method (D_VDB) should be larger than the gravitational mixing of the maximum power concept (D_MP), the calibration of the Van der Burgh method is more constrained. As a result, the Van der Burgh K and the dispersion at the boundary D_0 can be correlated with physically observable parameters through analytical equations, which makes the Van der Burgh method a predictive model that can be applied to alluvial estuaries worldwide.’

- Page 8, Table A1: “regularly” âAËŸT better “in this study”. ËĞ

Reply: It has been edited.

- Page 9: Please explain the terms used in the legend, such as HWS, LWS etc. Also,

it would help to relate the estuaries to the ones listed in Table 1.

Reply: The information has been added. HWS represents high water slack; LWS represents low water slack; TA represents the tidal average condition. Two columns name the estuaries and locations have been added in Table 1 in Page 25-26.

- Page 23, Figure 3: Please describe what the vertical lines are in the caption.

Reply: The vertical lines represent the location of the geometric inflection point. It has been mentioned in Line 6, Page 6, which is now added in the caption of Figure 3.

- Page 23, Figure 4: Please explain what the different symbols are, on the axes and in the Figure (link it to the estuaries in Table 1).

Reply: Indeed, the numbers represent the estuaries. Table 1 has been edited.

- Page 25, Table 1: What does “label” refer to? What is “S0”? What does the “*” refer to in the lines? This table needs more description. Also, I think it refers to the different estuaries, so it would really help to add the names of the estuaries here as well.

Reply: The labels were used to distinguish the estuaries. S_0 is the salinity at the inflection point, which has been mentioned in Line 4, Page 5. There may be more than one observations in a certain estuary, and ‘*’ is used to show which observations were chosen to be shown in Appendix B. The observations including the labels and estuaries’ name follows the dataset in the previous article (Zhang and Savenije, 2018), but as mentioned above, two columns name the estuaries and locations have been added in Table 1 in Page 25-26.

Additional Reference: Hansen, D. V. and Rattray, M.: Gravitational circulation in straits and estuaries, J. Mar. Res., 23, 104–122, 1965. Zhang, Z.: A theoretical basis for salinity intrusion in estuaries, Ph.D. thesis, Delft University of Technology, 2019.

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