Comments by Prof. T. Graf (Referee #1) and our responses

GENERAL COMMENTS

This paper presents an interesting combination of field and modeling studies of the tidally induced flow dynamics on a mangrove beach and a bald beach. The authors postulate that the freshwater recharge at the mangrove beach enables mangrove vegetation to grow, and that absent freshwater recharge at the bald beach prevents vegetation from existing. Numerical simulation results are also presented that reproduce field measurements of groundwater table at the two beaches very well. Both field and numerical studies helped to identify a low-permeability mud layer close to the surface, and a high-permeability aquifer below the mud layer (at both beaches).

The authors do a good job at interpreting their field observations in hydrogeological terms. It is also noteworthy that the numerical results reproduce the field measurements very well.

This being said, I am putting two points of criticism on the table:

Response:

We are very grateful to you for your recognition to our work. We have addressed your comments below.

Original comment 1-1:

1. The postulation that no freshwater recharge occurs at the bald beach is, in my opinion, not supported by the field observations. As a consequence, the no-flow boundary condition imposed on the landward (left) side of the bald-beach transect is not justified. The interpretation of the numerical results is too much driven by the imposed boundary condition. This should be changed, and the effect of different boundary conditions should be evaluated.

Response 1-1:

Closely following your suggestions, we have included extra field observation (observed salinity data) in the revised paper. We believe that the postulation of no freshwater recharge into the bald beach has been documented sufficiently based on the combined analyses of the information from sediments of the well cores, observed water table, and salinity data.

The new texts that we have revised to justify the no-flow boundary condition at the landward side of the bald beach are (lines 274-300 in the revised paper):

"From the panel for B0 in Figure 4b, one can clearly see that the observed water table at B1 was always greater than that at B0 during the whole observation period, indicating a landward groundwater flow direction, i.e. seawater intrusion. Thus there should be no inland freshwater recharge along this transect. Besides, the observed salinity at B1 was high during the whole observation period (almost constant about 28 ppt), but the observed salinity at B0 was very low (almost constant about 5 ppt, see panel B0 and B1 of Fig. 4b). On the other hand, during high tides the water table at B1 was ~1.4 m higher that at B0 (See Fig. 4b). Although the horizontal distance between B1 and B0 is small (~27 m), such a large head difference of 1.4 m did not cause significant variations of the water table and salinity at B0. These observations indicated that the well B1 is located in a high-permeability zone with good hydraulic connection with the tidal water but well B0 is in a much less permeable zone with very poor hydraulic connection with the tidal water. The soil properties around the two wells (Table 4) also support this conclusion. From Table 4 one can see that the sediments around B0 are mainly compacted clay, while that at B1 are dominated by sandy materials. Therefore, there was neither inland freshwater recharge during low tides nor seawater intrusion during high tides at the landward boundary of the bald beach. Otherwise, if there had been freshwater recharge from the inland, the freshwater recharge would have diluted the pore water at B1 during low tides, so that the salinity there would have decreased, rather than almost constant. On the other hand, if there is freshwater recharge from inland, which equivalently means that there had been good hydraulic connection between B0 and B1, then at high tides, the seawater at B1 would have definitely enhanced the salinity at B0 significantly.

In short, the landward side of the bald beach transect can be simplified into a no-flow boundary because this can quantitatively describe the observed significant tidal water table variations and high salinity data at B1, and also qualitatively explain the observed very low and almost constant water table and low salinity at B0."

In lines 334-341 of the revised paper, we also added the following discussions:
"During low tides, the salinities of both the deep and shallow locations at B7 remained high (about 26.5 ppt) and there was essentially no variation with depth. This was in great contrast with the large salinity difference between the shallow and deep locations at M8 and once again indicated that there was no inland freshwater recharge along the bald beach transect (otherwise, a freshwater discharge path near under the low tide line might dilute the salinity of shallow pore water at B7 and resulted in large salinity difference between shallow and deep waters at B7, which is not the case)."

In addition to the above modifications of our manuscript to justify the no-flow boundary condition, we have the following remarks as well:

1. The most intuitive way for the landward boundary of the bald beach is to set B0 as the landward boundary and to use the observed water table at B0 as the Dirichlet boundary condition of the groundwater flow in the transect. This boundary condition will, however, conceal the important fact that the inland freshwater recharge is negligible, and highlight the anomaly that the observed water table elevation at B0 was lower than the water table at B1 (see Fig. 4b).
2. It is very interesting to explore the anomaly that the observed water table elevation at B0 was always lower than at B1. We have provided a possible explanation of unknown pumping of groundwater in inland area near the bald beach transect (lines 304-306 in the revised paper). It is, however, beyond the

scope of this paper to quantitatively simulate the anomaly due to great, unknown uncertainties that caused this anomaly.

3. In order to eliminate the great, unknown uncertainties related to the observed water table anomaly at B0, we excluded B0 from the simulation domain and chose the vertical line 10 m landward of the high tide line (well B2) as the landward no-flow boundary of the bald beach.
4. The vertical boundary between B0 and B1 in Fig. 2b is only an approximate conceptual model representing the lower-permeability zone around B0 and the high-permeability zone near B1. For our purpose to compare the groundwater hydraulics along the two transects, the most important fact is that the bald beach transect has negligible freshwater recharge from inland, which is sufficiently evidenced by the sediments, pore water salinities and tide-induced water table fluctuations at wells B0 and B1. The low salinity and weak tidal signal in well B0 have been qualitatively explained as results of the low permeability zone around B0.

Original comment 1-2:

2. Much of what the authors explain is already known. The authors very correctly refer to existing literature when interpreting results or observations. The reader therefore wonders, what the novel aspect of this manuscript is? While I do see that field and numerical results are in excellent agreement, I would like to ask the authors to better highlight the novel aspect of their study.

Response 1-2:

Our manuscript includes the following novel aspects:

1) Although the importance of freshwater to the tidal marsh ecological system is already known, our study confirmed this by quantitatively correlating water levels and salinity profiles from the two sites through comparison study including both field observations and numerical modeling.
2) The two sites investigated here were found to have a mud-sand two-layered structure: a surface zone of low-permeability mud and an underlying high-permeability zone that outcrops at the high and low tide lines. The mud-sand two-layered structure plays a key role in the hydrological regime of the study areas.
3) We quantitatively investigated the groundwater-seawater circulation dominated by the high-permeability zone of mud-sand structure tidal marsh, which provides considerable contribution to the total submarine groundwater discharge (SGD).
4) To our knowledge, our work is the first paper to present the field data of groundwater flow and salinity in mangroves in China.
5) The last and most important aspect is the ecological implications arising from our study, as stated in the section “Conclusions”.

SPECIFIC COMMENTS

1. P5125 L19. tides

Response:
Corrected as advised. Thank you.

2. P5125 L20. have, effect ON the, exchange

Response:
Corrected as advised. Thank you.

3. P5126 L20,21. Permeability has dimension L2, while the number you give is a conductivity value in L T-1. Also, it is unclear whether 0.1 m day-1 is for the sand strata or for the mud layer.

Response:
We have replaced permeability with hydraulic conductivity. Thanks. The value of 0.1 m day^{-1} is for the upper mud layer, the deeper sand strata hold a value of hydraulic conductivity ranging from 0.7 to 1.8 m day^{-1}.

4. P5127 L10,11. Replace “by mean of comparisons of” by “Comparing”.

Response:
Corrected as advised. Thank you.

5. P5127 L23. What is a “shoalwater bay”?

Response:
The “shoalwater bay” means shallow water bay, we have changed it into “shallow water bay”.

6. P5127 L27. What do you mean by “best” reserve in China?

Response:
Dongzhaigang National Nature Reserve is the largest mangrove forest nature reserve in China, which holds the most abundant mangrove species, and has been giving the best protection.

7. P5128 L1. An average value is just one value, not a value range.
8. P5128 L2. Delete “around”.
9. P5128 L13+17 and other places in the ms. Delete “.0”.
10. P5132 L5. ...higher than that of the...

Response:
All above advised corrections have been fully accepted. Thank you.

11. P5132 L11-16. Not exactly clear what you mean by “discharge tube”. You simply mean the high-K zone below the mud layer.

Response:
Tidal forcing across a sloping beach leads to the formation of an upper saline plume (or surficial mixing zone) in the intertidal region, in addition to the classical saltwater wedge. The upper saline plume and the saltwater wedge confine a freshwater discharge ‘‘tube’’, which pinches out near the low tide mark. This kind of tube was

observed by Boufadel (2000) in a laboratory beach and by Robinson et al. (2006) in the field. Many numerical simulations of groundwater flow and salt transport in the intertidal zone predicted this kind of tubes near the low tide line. In terms of the high-K zone below the mud layer, it is only beneficial but not a necessary condition to the forming of the groundwater discharge tube.

Citations:

Boufadel, M. C.: A mechanistic study of nonlinear solute transport in a groundwater-surface water system under steady state and transient hydraulic conditions, Water Resources Research, 36, 2549-2565, 2000.

Robinson, C., Gibbes, B., and Li, L.: Driving mechanisms for groundwater flow and salt transport in a subterranean estuary, Geophys. Res. Lett., 33, L03402, doi:10.1029/2005GL025247, 2006.

12. P5133 L3-6. What is mean sea level at transect B?

Response:

The mean sea level at transect B is 1.181 m (shown in Table 4). Following your comments, we have given the value in this sentence.

13. P5133 L7,8. Why do you say “during falling tides and low tides” and not simply “during falling tides”, which is what Fig. 4 suggests?

Response:

Corrected as advised. Thank you.

14. P5133 L7-21. What observation makes you conclude that water near B1-B3 drains seaward? I do see that the scale for B1 in Fig. 4 is different from those for B2 and B3. Considering this, it seems like the water table in B3 is higher than in B2 than in B1. So we have a hydraulic gradient that points landward, not seaward. Could you explain this?

15. P5134 L8-15. Your observations so far do in my opinion not support conclusion (2). What physical observation makes you conclude item (2)?

16. P5135 L1. Given my previous comment, I do not see why a no-flow BC is justified.

Response:

We have addressed all above comments, please see **Response 1-1**.

17. P5135 L8-11. I do not see from Fig. 2 that there is a “bed of the tidal river”. Please clarify.

Response:

The bed of the tidal river is shown with the code ③ and its legend in Fig. 2.

18. P5135 L24-26. Not clear what is symmetric. Please indicate better in Fig. 2.

Response:

Following you comments, we have marked the middle line of the tidal river in Fig. 2.

19. P5136 L1-7. Should indicate more clearly where all these zones are. Maybe in a figure showing the complete conceptual model?

Response:

All these zones are indicated in Fig. 2. In response to your comments, we have added a statement here to guide readers to Fig. 2. It reads (line 406 in the revised paper): "The locations of all these zones are indicated in Fig. 2."

20. P5136 L12ff. I am unsure what a time-averaged plot of fluxes is telling us. Is this really the net flow of water? I think not because you are averaging extremes. I think it would be more appropriate (and interesting) to focus on time-dependent fluxes across a cross-section, for example at x=50 m. Then you could average that Q-t graph to give an average Q across that cross-section. If the averaged Q is positive, the net flow of water is indeed seawards.

Response:

Thank you for your proposed method. We agree that, for characterizing the flow patterns in a specified cross-section, presenting the time-dependent flux (Q-t graph) is a very good method. However, such an approach fails to give the readers the global flow velocity field in the whole domain. The time-averaged plot of pore water velocity shows the flow patterns across whole beach succinctly and conveniently. It is really the net flow. Owing to these, the time-averaged plot of pore water velocity has been widely used in our previous studies (e.g., Guo et al. 2010; Li and Boufadel, 2010; Xia et al., 2010). Due to these reasons and the for the sake of succinctness, we would like to decline the reviewer's suggestion.

Citations:

Guo, Q., Li, H. L., Boufadel, M. C., and Sharifi, Y.: Hydrodynamics in a gravel beach and its impact on the Exxon Valdez oil, J. Geophys. Res., 115, C12077, doi:10.1029/2010JC006169.

Li, H. L., and Boufadel, M. C.: Long-term persistence of oil from the Exxon Valdez spill in two-layer beaches, Nature Geoscience, 3, 96-99, 2010.

Xia, Y. Q., Li, H. L., Boufadel, M. C., and Sharifi, Y.: Hydrodynamic factors affecting the persistence of the Exxon Valdez oil in a shallow bedrock beach, Water Resources Research, 46, W10528, doi:10.1029/2010WR009179, 2010.

21. P5136 L22. Could you show locations of all M in Figs. 7,8 (same for B)?

Response:

We have shown all well locations in these figures. Thank you.

22. P5136 L23-25. While I agree that the conceptual model of two layers having different permeability is supported by the results, I still do not see that having freshwater recharge for M, and no freshwater recharge for B is shown.

23. Figs 8+10. If you put your hand over results between x=0 and x=20 m, then the two results look very alike. This gives rise to the question, why you

imposed different flow BC along the left boundary, and by what this different choice is supported?

Response:

Thank you, we have addressed all above comments, please see **Response 1-1**.

24. P5136 L28. “except that there was no inland freshwater recharge in the bald beach”. You only observe the BC that you imposed! This is not a physically relevant observation but rather a numerical issue (BC) that you require to solve differential equations. Should be careful here not to mix physics with numerics.

Response:

Thank you, we have addressed this comment, please see **Response 1-1**.

25. P5137 L12. Again, I wonder what physical observation justifies the no-flow BC, and I also wonder what the results might look like if you change the left BC from Neumann no-flow to Dirichlet constant-head. I would expect that the results would actually be quite similar. Plus, I would argue that there is always freshwater recharge, simply because freshwater falls over land, and because land is higher than sea level.

Response:

Thank you, we have addressed this comment, please see **Response 1-1**.

26. P5138 L3-16. The logical implication of the vast similarity must be that BCs of M and B are also identical.

Response:

By coupling the discussion of salinity difference along the two transects, this section has been updated into “Comparison between the two transects”. Please see lines 453-497 in the revised paper.

27. Conclusions. So the key point of the paper is that B exists because there is no freshwater recharge, and that M exists because there is freshwater recharge. First, I wonder how impactful this finding is. Quite obviously, living organisms thrive when getting (fresh) water, and they disappear when there is not (fresh) water input. Second, I still wonder what hydrological observation supports your assumption of the BCs along the left boundary. Third, while I do believe that freshwater recharge at M is larger than that at B, could this difference be associated with the mere fact that plants use up water, thus creating a lack of water in the subsurface which attracts freshwater to flow in? Hence the difference in freshwater recharge?

Response:

We think that in **Response 1-2** we have adequately addressed the first point of the comments. The second point is detailed in **Response 1-1**. The third point is essentially in line with our conclusions as along as the no-flow landward boundary condition along the bald beach is valid. That is, the possibilities for the seeds of plants to root are same for the bald beach and mangrove transects. In the bald beach there is no freshwater to attract so the plants are not able to grow up or develop even if they can root. In the mangrove transect, however, there is freshwater to attract so the plants are able to grow up and develop once their seeds root.

28. Fig. 1. I wonder whether transect M is actually a “beach”. It looks like M is already situated within land. Could you have picked a location that is about 600 m east of M on the beach? That location looks more comparable to B because then both would be situated in the Dongzhaigang Bay. I wonder what effect the choice of location of the Mangrove transect on your observation is, and whether M and B can actually be compared. Please address this.

Response:

When choosing the mangrove transect, we comprehensively considered several important factors besides the distance between the two transects. They include e.g., logistic conveniences, human activities around the transect, and approval from the local administration. There are other mangrove transects closer to the bald beach transect, but we were not allowed to conduct field study there by one or more of these factors. In addition, at present stage, we have to consider the limitation of our fund that supports this study. We will, however, pursue opportunities to conduct a set of improved field experiments that include all the suggestions by the reviewers and the editors in the future.