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Interactive comment on "The physics behind Van der Burgh's empirical equation, providing a new predictive equation for salinity intrusion in estuaries" *by* Zhilin Zhang and Hubert H. G. Savenije

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We would like to thank referee #2 for his/her detailed reading and valuable comments. It triggered us to further consider the results obtained and it helped us to formulate better what precisely the implication is of a larger range of Van der Burgh's K. As a result of your comments we shall modify the paper, particularly the discussion of the results obtained.

1. The first comment of Referee #2 is very similar to the one made by Referee #1. We replied to it there in much detail. In the revised paper, we shall try to estimate what

the uncertainties are that may have affected the wider range of K values (observational errors, schematization errors, underlying assumptions, and the fact that the model is for steady state, whereas an estuary is never in steady state). Also we should realize that the mixing length used in our empirical model is the tidal excursion (appropriate for well-mixed estuaries) while for more stratified estuaries, the mixing length is the depth. The authors used the tidal excursion because it appears that tide-driven mixing is dominant in well-mixed estuaries (e.g., Wei et al., 2016) and we assumed that most estuaries achieve a more well-mixed condition, especially during spring tide and low flow when the salinity intrusion becomes an issue. Hence, the correct mixing length to use (E or h) may depend on the stratification, which the authors will study further.

2. We have redrawn Figure 5 taking into account 25 % sensitivity of fresh water discharge (x-err) and calibration errors (y-err).

After inclusion of these uncertainty bounds, we can still see that the predictive method overestimates the low calibrated K values, and underestimates the high values. Or, that the range of (1/2, 2/3) appears too narrow. The reasons are that the predictive method does not consider the tide-driven mixing (which draws the predicted K-value further down) and that for high K-values the 2-D vertical theoretical approach underestimates lateral density driven mixing (which would increase the high values), as discussed in the reply to reviewer #1. So in estuaries with a low predicted K-value (which do not have much stratification) the K value should be even smaller as a result of tidal mixing; in estuaries with a high predicted K-value (which do have substantial stratification) the K value should be even larger due to complex 3-D density-driven circulation. In the central reach, the prediction by MacCready's equation is not bad.

In addition, there are some outliers. The outliers in estuaries #1 and #12 (Kurau and Lalang), which have very high calibrated K values, density effects may be so strong that they cause three-dimensional gravitational circulation, or the fresh water discharge may have been substantially underestimated. On the other hand in the Thames estuary (#8) tide-driven dispersion, such as tidal trapping, may have considerable influence.

3. In wide estuaries, strong residual circulation develops as a result of separate flows through the preferential ebb and flood channels that meet at cross-over points where fresh water from upstream mixes with saline water from downstream. The length of such channels is in the order of the tidal excursion. We introduced this additional tide-driven mechanism in the wider part of the estuaries by an introduction of an additional lateral dispersion factor of (1+C2(B/E)2). This factor adds lateral exchange flow and enlarges the value of the dispersion, leading to a bending down of the simulated salinity curves near the (wide) mouth. When C2=10, the salinity curves (14 out of 18 estuaries) bend down perfectly fitting the observations. Possible reasons for these outliers as well as the poor fit in the downstream parts of the Lalang and Chao Phraya have been discussed in Section 4.2 of the paper. So instead of using a different C2 factor for each estuary, a constant value has been used so as to make the calibration simpler and more consistent.

Reference:

Wei, X., Schramkowski, G.P., Schuttelaars, H.M., 2016. Salt dynamics in well-mixed estuaries: importance of advection by tides. Journal of Physical Oceanography, 46(5), 1457-1475.

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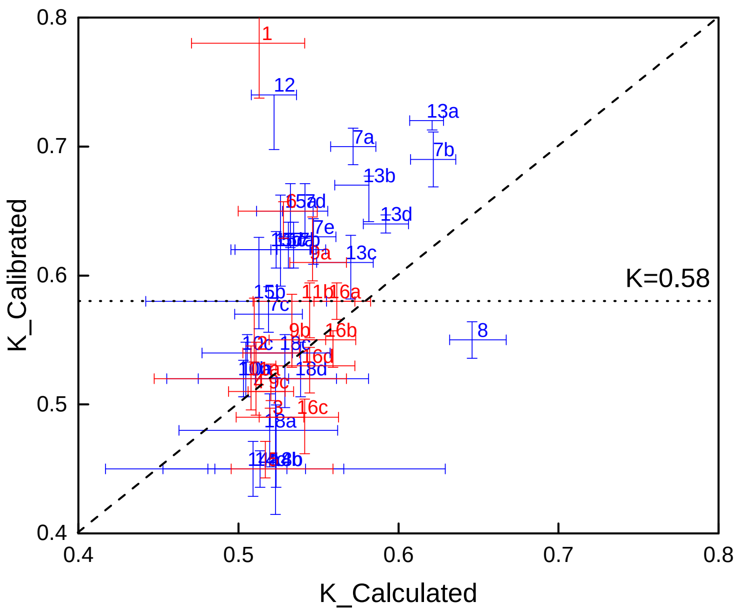

Fig. 1. Figure 5