Dear Anonymous Referee#2,

We are very much grateful for your valuable and fruitful comments to improve our manuscript (hess-2010-332). The referee comment is given in blue font and the answer in black font.

1. Specific comments:

If v and K are constant the derivation is straightforward as described in the paper. However, if both parameters are functions of x the result becomes different. Comparison of this equation with Eq. (S5) (or Eq. (S6)) shows that there is no simple relationship between v and K. The authors should clarify whether and how this is captured by their analysis.

Answer:

Van der Burgh (1972) developed an empirical method on the basis of the effective tidal average dispersion under equilibrium conditions. The longitudinal variation of the effective dispersion is given as follows:

$$\frac{\partial[D(x)]}{\partial x} = K(x)\frac{Q}{A(x)} \quad (1)$$

where $D(x)$ is the longitudinal dispersion coefficient, Q is the river discharge, $A(x)$ is the tidal average cross-sectional area and $K(x)$ is the dimensionless Van der Burgh's coefficient. As Q has a negative sign, the dispersion decreases upstream (Savenije, 2005). $K(x)$ determines the relative weights of the tide-driven and density-driven mixing mechanisms (Savenije, 2005). If K is small, then tide-driven mixing is dominant to transport salt. If K approaches 1, density-driven mixing is dominant to transport salt.

Hansen and Rattray (1965) assumed that the salinity in the central zone of a narrow estuary with a constant cross-section would decrease linearly. The tide-driven dispersion D_t is then given as follows (Savenije, 2005):

$$\frac{\partial D_t(x)}{\partial x} = \frac{Q}{A(x)} \quad (2)$$

In addition, Hansen and Rattray (1965, 1966) defined the estuarine parameter v by the fraction of the salt advected seaward with the river discharge (vSQ/A) that is balanced by the upstream salt flux associated with tidal dispersion ($D\partial S/\partial x$). As a consequence, under steady state conservation of the mass equation for salt, v equals the proportion of the tide-driven dispersion $D_t(= D\partial S/\partial x)$ to the total dispersion $D(= SU_f = SQ/A)$ (Savenije, 2005). v can explicitly be given as a function of x.

$$v(x) = \frac{D_t(x)}{D(x)} = \frac{D(x)A(x)}{SQ}\frac{\partial S}{\partial x} \quad (3)$$

If v approaches 1, the upstream transport of salt is entirely dominated by tide-driven processes. If v is close to 0, the up-estuary salt transport is almost entirely by gravitational circulation. If $0.1 < v < 0.9$, the system experiences a contribution of both gravitational circulation and tide-driven dispersion to the upstream transport of salt (Hansen and Rattray, 1966; Bowden and Gilligan, 1971; Officer and Kester, 1991; Dyer, 1997; Savenije, 2005; Valle-Levinson, 2010). Equation (3) was used to calculate estuarine parameter v in this study. A combination of equations (2) and (3) is as follows:

$$\frac{\partial[v(x)D(x)]}{\partial x} = \frac{Q}{A(x)} \quad (4)$$

or

$$\frac{\partial[D(x)]}{\partial x} = \left\{\frac{1}{v(x)} - \frac{D(x)A(x)}{v(x)Q}\frac{\partial[v(x)]}{\partial x}\right\}\frac{Q}{A(x)} \quad (5)$$

The relation between the Van der Burgh's coefficient *K(x)* and the estuarine parameter $v(x)$ for the case with spatially varying v and K can be written as follows according to Anonymous referee#2 (Eq.6).

$$K(x) = \frac{1}{v(x)}\left\{1 - \frac{D(x)A(x)}{Q}\frac{\partial[v(x)]}{\partial x}\right\} \quad (6)$$

The longitudinal dispersion coefficient $D(x)$ is used to characterize the overall diluting capacity of an estuary. $D(x)$ can be calculated from integrated salt balance equation with respect to x where the salinity of freshwater inflow is assumed as zero (Dyer, 1997: p. 79; Lewis and Uncles, 2003; Savenije, 2005: p. 154).

$$D(x) = \frac{QS(x)/A(x)}{\frac{\partial S}{\partial x}} \quad (7)$$

Thus $D(x)$ can be calculated along the Sumjin River Estuary as Q, $A(x)$, and the longitudinal salinity distribution (S) are known. The numerator represents the advective rate of transport of salt towards the sea by the river flow, Q per unit area of cross-section $A(x)$ and this is countered by the landward flux of salt due to non-advective processes. The denominator represents the longitudinal salinity gradient. Equation (7) is strictly inapplicable to stratified conditions (Dyer, 1997) and is a coefficient of effective longitudinal dispersion for well-mixed estuaries (Dyer, 1997; Savenije, 2005). On the basis of the stratification parameter ($\delta S/\langle S\rangle$), which is the ratio of the top-to-bottom salinity difference δS to the depth mean salinity $\langle S\rangle$, strongly stratified conditions were found in the SRE during neap tide whereas well- to partially-mixed conditions during spring tide (Shaha and Cho, 2009). Therefore, this study will discuss only the spring tide condition throughout the paper.

The *K* values calculated with Eq. (6) do not lie within the recommended ranges (0<*K*<1) given by Savenije (1993, 2005) and Eaton (2007). *K* values of Eq. (6) exceed the recommended range of 1 where $\partial S / \partial x$, $\partial v / \partial x$ and second term of Eq. (6) are >2.0 psu, >0.0666 and <0.5, respectively (Table 1). The salinity curve exhibits an exponential decline, where the salinity decreases sharply and the *K* values of Eq. (6) exceeded the recommended limit in this location. In an exponential function, the function value is directly proportional to its gradient (Savenije, 2005). In addition, McCarthy (1993) showed how the dispersion decreases upstream and becomes zero near the toe of the salt intrusion curve in an estuary with an exponentially varying width. He used an exponential function, with a ratio of the dimensionless diffusion length scale to the tidal dissipation length scale. The dimensionless diffusion length scale is defined as the ratio of K_x / R, where K_x is the longitudinal eddy diffusivities. *R* is the ratio of the dimensional river flow to the scale for the nonlinear flow. *R* cannot exceed order one (McCarthy, 1993).

In this study, an exponential function is also assumed with the proportion of tide-driven dispersion to the total dispersion (D_t / D), which limits the *K* value to within one in an exponential shaped estuary, and describes the relative strength of tide-driven (*K* ~ 0) and density-driven mixing (*K* ~ 1) for the transport of salt (Table 1). To satisfy the conditions for an exponential shaped estuary, the spatially varying *K* is proposed in this study as follows:

$$K(x) = \frac{1}{\exp(v(x))} \left\{ 1 - \frac{D(x)A(x)}{Q} \frac{\partial [v(x)]}{\partial x} \right\} \quad (8)$$

In this new calculation, if *K* < 0.3, the up-estuary salt transport is entirely dominated by tide-driven mixing during spring tide near the mouth (Fig. 1). If 0.3 < *K* < 0.8, both tide-driven and density-driven mixing contribute to transporting salt in the central regimes. If *K* > 0.8, the salt transport is almost entirely by density-driven circulation in the upper most regimes.

Table 1. Different parameters of Eqs. (6) and (7) used to calculate spatially varying *K*

Distance	$\partial v / \partial x$	$\partial S / \partial x$	2nd term of Eq. (6)	*K* from Eq. (6)	*K* from Eq. (8)
0.54	0.0178	0.5767	0.980	0.052	0.058
1.63	0.0103	0.3346	0.955	0.049	0.064
2.71	0.0110	0.3559	0.940	0.046	0.079
3.77	0.0190	0.6139	0.925	0.057	0.085
4.80	0.0185	0.5980	0.896	0.073	0.108
5.85	0.0297	0.9534	0.870	0.104	0.130
6.90	0.0363	1.1706	0.839	0.136	0.159
7.86	0.0293	0.9513	0.796	0.180	0.193
8.76	0.0325	1.0526	0.761	0.247	0.228
9.72	0.0426	1.3828	0.725	0.301	0.312
10.72	0.0360	1.1683	0.677	0.371	0.330
11.72	0.0389	1.2618	0.639	0.478	0.330
12.68	0.0474	1.5414	0.599	0.573	0.371
13.65	0.0426	1.3859	0.541	0.689	0.423
14.61	0.0505	1.6347	0.493	0.929	0.471
15.59	0.0666	2.1667	0.442	1.213	0.532
16.62	0.0666	2.1668	0.374	1.579	0.615
17.68	0.0669	2.1739	0.309	2.550	0.693
18.77	0.0702	2.2862	0.252	5.232	0.759
19.85	0.0758	2.4696	0.195	9.320	0.831
20.88	0.0813	1.9576	0.131	19.340	0.915
21.87	0.0804	1.7867	0.104	76.340	0.973
22.87	0.0811	1.83	0.063	86.749	0.987

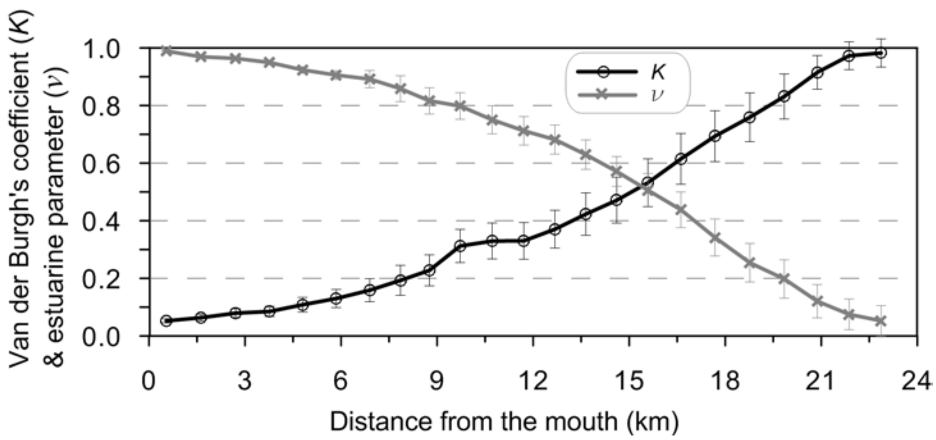

Fig. 1. Spatial variation of the median estuarine parameter (v) and Van der Burgh's coefficient (K) along the Sumjin River Estuary. If $v \sim 1$ and $K < 0.3$, up-estuary transport of salt entirely by tide-driven mixing. If $v \sim 0$ and $K > 0.8$, up-estuary salt transport almost entirely by gravitational circulation. If $0.1<v< 0.8$ and $0.3<K< 0.8$, both gravitational circulation and tide-driven circulation contribute to transporting salt up-estuary.

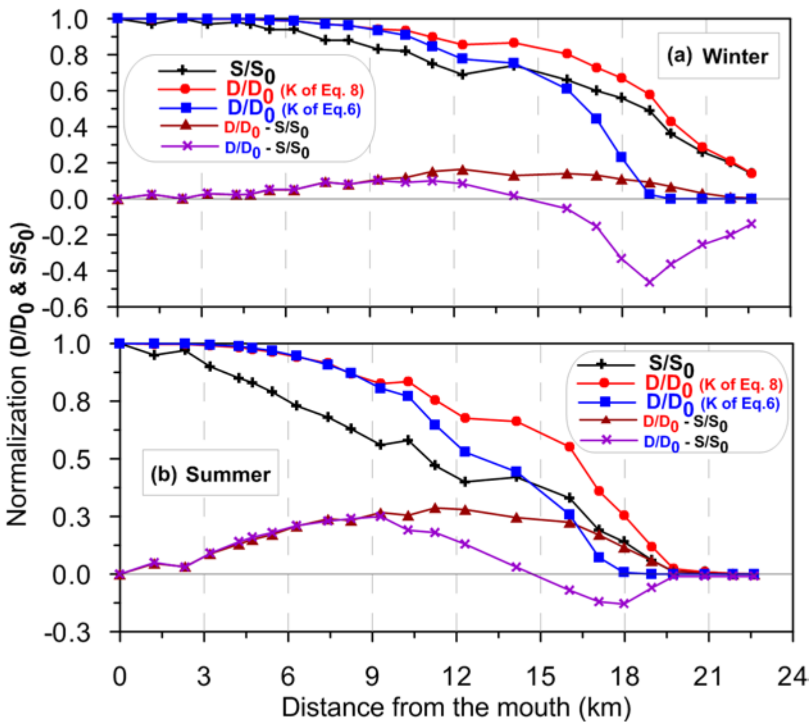

Fig. 2. Normalized dimensionless dispersion curves during (a) winter (discharge 19 m^3s^{-1}) and (b) summer (discharge 50 m^3s^{-1}) in the Sumjin River Estuary.

Figure 2 depicts how the normalized dimensionless dispersion curves perform in relation to the observed salt intrusion curves during winter (discharge 19 m^3s^{-1}) and summer (discharge 50 m^3s^{-1}) in the Sumjin River Estuary. Equation (S7) (HESSD, Shaha and Cho) has been solved using the spatially varying K derived from the above Eqs. (6) and (8). The spatially varying K of Eq. (6) gives negative density-driven dispersion after approximately 15 km from the estuary mouth where *K* values exceeds the recommended range of 1. However, negative density-driven dispersion has no physical meaning. In contrast, the spatially varying *K* of Eq. (8) consistently represents density-driven dispersion (Fig.2).

The main constraint of Eq. (S6) suggested by Shaha and Cho (published in HESSD) is that this equation can not calculate the lower bound value of <0.37 for *K*. However, the above equation with an exponential function (Eq.8) is now able to deduce *K* values of <0.37 which has been found by Savenije (2005) for various estuaries.

Specific comments on the text are given as follows.

Cross-sectional area (m^2), width (m) and depth (m) at cross-sections of all CTD stations of the Sumjin River Estuary will be shown in separate figure in the final revised paper (Fig. 3). SMS (Surface Water Modeling System) grid generation software (version 8.1) is used to calculate cross-sectional area (m^2), width (m) and depth (m) at each cross-section of all CTD stations. The remaining parameters such as river discharges, tidal range and salinity at the estuary mouth is shown in Table 2, although all are availabe in Shaha et al. (2010) and Shaha and Cho (2009). Table 3 shows the convergence length for the area (a) and width (b) at CTD station of the Sumjin River Estuary. The repeated text will be removed in the final revised paper.

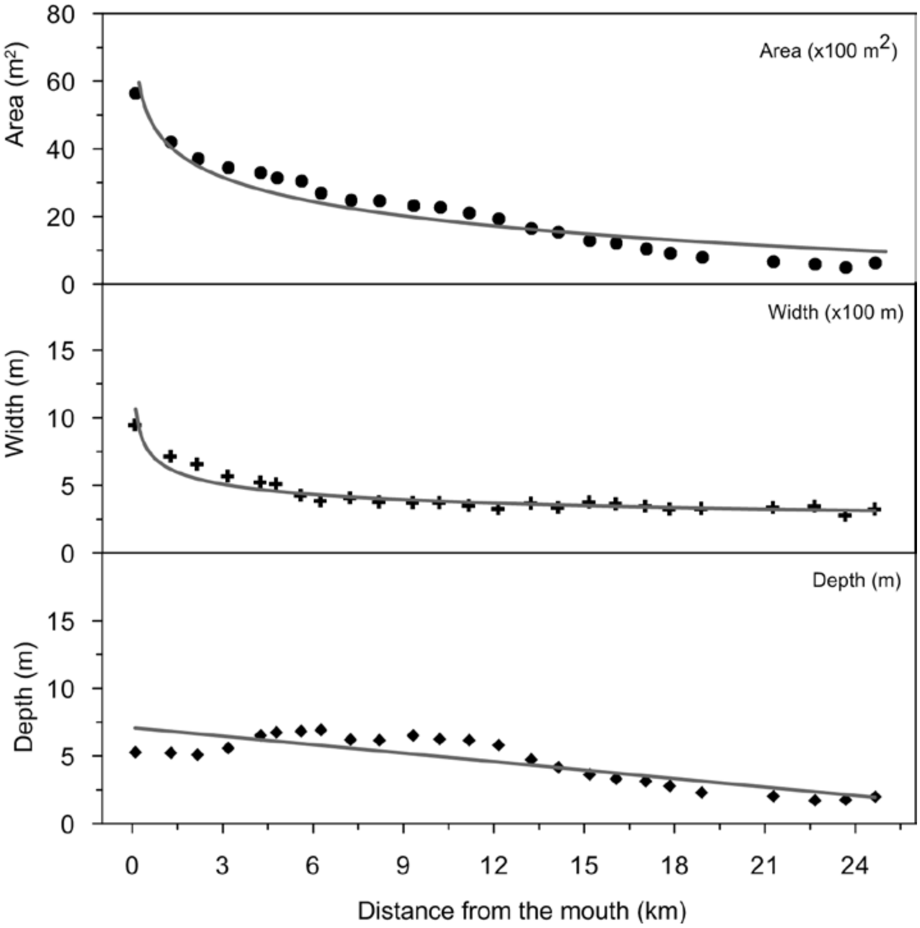

Fig. 3. Cross-sectional area (upper), width (middle) and depth (bottom) of all CTD stations of the Sumjin River Estuary.

Table 2. River discharges, salinity (S_0) and tidal ranges at the estuary mouth during field observations

Time	Discharge (m^3s^{-1})	Salinity	Tidal range (m)
03 Aug 2004	46	31.46	3.09
16 Oct 2004	29	31.16	3.86
29 Jan 2005	10	32.43	3.14
08 Apr 2005	18	33.57	3.51
21 Jul 2005	58	30.46	2.45
19 Oct 2005	16	31.59	3.92
16 Jan 2006	20	32.55	3.17
30 Mar 2006	11	33.51	3.84
10 Aug 2006	50	30.00	2.93
06 Nov 2006	9	31.83	3.99
20 Jan 2007	12	32.94	3.85
03 Apr 2007	21	32.95	3.03
Average =	**25.0**	**32.1**	**3.4**

Table 3. Convergence length for the area (a) and width (b) at CTD stations of the Sumjin River Estuary

Distance	Convergence a (m)	Convergence b (m)
1.08	6741.54	5214.46
2.17	7533.12	6980.37
3.25	9134.54	7408.88
4.29	10352.35	8605.30
5.31	11227.60	8676.07
6.39	11637.89	9180.05
7.4	12536.79	10500.54
8.31	13003.37	10720.02
9.21	13025.79	10852.91
10.23	13493.28	12490.15
11.21	13729.45	14361.44
12.21	13657.90	14785.85
13.15	13637.49	14744.96
14.14	13303.50	16980.71
15.08	12760.83	19456.32
16.09	12440.30	19444.87
17.14	12016.67	19273.65
18.22	11695.37	20877.65
19.32	11441.84	22532.56
20.37	11094.89	19918.94
21.38	10722.01	22424.05
22.36	10507.09	15824.52
23.89	8839.26	16565.32

Page 8785, line 27: decrease to 12 and 8% or decrease with 12 and 8% (probably the last).

Answer: This will be fixed in the final revised paper.

Page 8786, line 25: a linear decrease of the salinity is also assumed for each individual section in the estuary?

Answer: A linear decrease of salinity has not been assumed in this study.

Page 8787, line 15: I would suggest to move this line to Section 4 where the methodology is really applied to the Sumjin estuary (in fact this sentence is already there, see line 13-15).

Answer: This will be fixed in the final revised paper.

Page 8788, line 16 and 17: please define the dimensionless diffusion length scale and the tidal dissipation length scale, because in this way it is not very instructive to the reader.

Answer: The dimensionless diffusion length scale is defined as the ratio of K_x/R, where K_x is the longitudinal eddy diffusivities. R is the ratio of the dimensional river flow to the scale for the nonlinear flow. R cannot exceed order one (McCarthy, 1993).

Page 8789, line 5 and 6: what is meant with "… supports the K-based dispersion equation…".

Answer: As K-based dispersion has discussed in the discussion session, this will be moved from Methodology to avoid confusion.

Page 8789, line 24: "…is almost entirely dominant landward of 6 km…". I assume that landward should be seaward? This has been formulated wrongly several times hereafter.

Answer: The observation was started from CTD station one located in Gwangyang bay (Fig. 1, published in HESSD) landward (upstream) which has been mentioned in section 2. Therefore, landward term is used to explain the salt transport mechanism proceeding upstream (landward) from CTD station one. I think this has not been formulated wrongly. To avoid confusion, this sentence will be rewritten as "landward from the mouth up to 6 km".

Page 8789, line 25: Please indicate for which values of $\partial S / < S >$ well mixed or stratified conditions are present. It would be nice to show this parameter in a figure (it is not included in the paper by Shaha and Cho (2009)).

Answer: This figure has included in Shaha and Cho (2009) with the details of values for well mixed and stratified conditions (Fig. 7, Shaha and Cho, 2009).

Page 8790, line 8: "Landward from 6 to 21 km…". I assume that between 6 and 21 km is meant.

Answer: This will be fixed in the final revised paper.

Page 8790, line 12: Please define potential energy anomaly (in words or by means of an equation), because in this way it is rather vague to the reader.

Answer: This will be fixed in the final revised paper.

Page 8791, line 2: which calculation is meant (the previous text?) and in what way is there consistency?

Answer: The scaling of K has described during spring tide. The same approach of spring tide had followed during neap tide. The sentence will be rewritten in the final revised paper to avoid confusion.

Page 8791, line 10: Seaward in stead of landward? See also Page 8792, line 3 and other lines in the text.

Answer:'Landward of 6 km from the mouth of the estuary, the transport of salt is entirely dominated by tide-driven mixing, where $v < 0.9$.' (exiting one)

'Landward from the mouth of the estuary up to 6 km, the transport of salt is entirely dominated by tide-driven mixing, where $v < 0.9$ (this will be inserted in the final revised paper).'

Page 8791, line 15: Note that according to Eq. (S6) K can never be less than 0.37 (~0.4).

Answer: This problem has been solved using Eq. (8) given above.

Page 8791, line 17: "… during neap tide". Thus the preceding text was for spring tides? Please indicate more clearly.

Answer: This will be fixed in the final revised paper.

Page 8791, line 20-21: Please note that K values of 0.25 and 0.3 can never be computed with Eq. (S6) using $0<K<1$.

Answer: This problem has been solved using Eq. (8) given above.

Page 8791, line 27: this is apparently for spring tide

Answer: This will be fixed in the final revised paper.

Page 8793, line 23-24: The text is repeated from Page 8792, line 4-6.

Answer: This will be removed in the final revised paper.

Page 8794, line 8: "To be sure …". The meaning is unclear.

Answer: This sentence will be clear in the final revised paper.

2. Technical corrections

Figures 2 and 3: Please indicate units along vertical axis.

Answer: Van der Burgh's coefficient is dimensionless.

Figures 6 and 7: It is not clear whether S/S0 relates to observed or computed values.Please include a Figure showing the observed salinity distribution for the conditions presented (spring, neap, summer, winter).

Answer: *S/S0* is the normalized observed salinity showing in black line with plus symbol in Fig. 6 and 7 during spring, neap, summer and winter.

All remaining minor technical corrections will be inserted in the final revised paper.