Earth Surf. Dynam. Discuss., 1, C658–C674, 2014
www.earth-surf-dynam-discuss.net/1/C658/2014/

Interactive comment on "Velocity and concentration profiles of saline and turbidity currents flowing in a straight channel under quasi-uniform conditions" *by* M. Stagnaro and M. Bolla Pittaluga

M. Stagnaro and M. Bolla Pittaluga

mattia.stagnaro@unige.it

Received and published: 14 February 2014

Let us first thank Reviewer #1 for your constructive comments and the careful scrutiny of our paper that certainly improved the quality of our manuscript. Below we provide a point by point reply to the issues raised in your review that are here reported in bold.

Comment 1) There is an extensive body of literature that was neglected in the article. See for instance, work published between mid 80's to mid 90's by Gary Parker's research group and collaborators. Some articles are directly related to

the experiments reported in the current manuscript. I encourage the authors to review the following papers:

- **Parker, G., Garcia, M., Fukushima, Y., and Yu, W. (1987). Experiments on turbidity currents over an erodible bed. J. of Hydraulic Research, 25, 123 – 147.**
- **Garcia, M. (1994). Depositional turbidity currents laden with poorly sorted sediment. J. of Hydraulic Engineering, 120 (11), 1240 – 1263.**
- **Garcia, M. (1985). Experimental study of turbidity currents. M.S., University of Minnesota.**
- **Garcia, M. (1989). Depositing and eroding sediment-driven flows: Turbidity currents. Ph.D. University of Minnesota.**

The authors should discuss similarities/differences between previous published experiments and their experiments.

We have followed the referee's suggestion including the mentioned papers published on scientific journals in the revised version of the manuscript (lines 40–64). We report the text below for your convenience:

Parker et al. (1987) performed a series of experimental observations on turbidity currents flowing over an erodible bed. Such pioneering experiments were employed to establish approximate similarity laws for the velocity and concentration distributions. Normalized velocity and concentration profiles showed a similarity collapse indicating little systematic variation in grain size or bed slope. However, only supercritical currents were studied and the vertical structure was strongly affected by the presence *of bedforms invariably found at the end of experiments. In a subsequent experiment, Garcia and Parker (1993) studied the spatial evolution of saline underflows allowed to flow down an inerobible 5 m long sloping bed with the slope fixed to 0.08, followed by an horizontal reach. In the first reach a trench filled with sediment was created to allow accurate experimental determination of the ability of the current to entrain sediments. The same experimental setting was then employed by Garcia (1994) to study the depositional structure of turbidity currents laden with poorly sorted sediments. The similarity collapse of measured flow velocity was quite good for the supercritical region of the flows, but, on the other hand, the data collapse for the subcritical region of the flows showed a fair amount of scatter.*

Comment 2) Text below Eq. (2) indicates that 'the upper limit of integration... as the height at which u = 0.3U' Why?

In order to determine the mean values of velocity U and height h from the velocity profiles, employing the equations (1) and (2) of our paper, it is necessary to define an upper limit of integration z_∞. The choice of z_∞ slightly influences both the values of U and h, as shown in the Figure 1. Our choice was motivated by the observation that if that upper limit of integration was employed, then there was a good agreement between the flow thickness computed from the integration of the longitudinal velocity profile and that extracted visually from the lateral sidewall. Different choices, however, would not have led to qualitatively different results. This has been pointed out in the revised version of the paper (lines 213-219).

Comment 3) Figure 5: Blue dots in the initial four profiles are consistently below the flow interface recorded during the experiments. The agreement between line and dots improves significantly in other profiles. The authors should discuss this point and provide a hypothesis for this particular behavior. Where was the

submerged hydraulic jump in that experiment?

For all the experiments the thickness of the current in the upstream cross section is determined by the height of the sluice gate from the bottom. We decided to impose a supercritical condition for all the currents performed. However, as it is shown in Table 1 in the paper, the currents flowing along the flume are both subcritical and supercritical. In the first case (subcritical) we observed an hydraulic jump located immediately downstream from the inlet cross section, whereas in the other case (supercritical) the current changes its configuration adjusting its height and velocity proceeding downstream.
In all the experiments we noticed that the distribution of flow velocity was influenced by the inlet condition in the first portion of the flume, approximately 0.5 m. Downstream, there was a transition zone, which varied its extension depending on the currents, characterized by a length of approximately 2.0 m.
As a consequence the profiles of the first measuring sections were affected both from the inlet condition and from the presence of the hydraulic jump. It is possible to notice, from Figure 5 in the paper, that the shape of the velocity profiles in the first four sections differ from the others. This fact can be better appreciated by observing the new Figure 5b of the paper, where it is possible to better observe this difference. Also, in Figure 2 it is possible to notice that the value of h is strongly influenced by the velocity profiles shape, and it is lower in section C1 and higher in section C9. In our view, these are the reason for this particular behaviour noticed by the referee.

Comment 4) Table 1: The article will benefit if the submerged–hydraulic jump locations are provided

The location of the hydraulic jump was difficult to detect with precision, since the flow was characterized by some waves downstream from the inlet cross section. However, the hydraulic jump was approximately located in the first 2 meters of the flume (see Figure 3).

Comment 5) Figure 6 b: This plot is very similar to plots given in Figure 8a of reference a, and Figure 9a of reference b provided in comment 1. The authors should include data from those references in the graph to compare the experiments.

In Parker *et al.* (1987) (their Fig 8a) the authors shows the longitudinal velocity profiles of 7 experiments. The main characteristics of these experiments are summarized in Table 1 and the velocity profiles are shown in Figure 4a.

run	U_0 (cm/s)	h_0 (cm)	C_0 10^{-3}	Ψ_0 (cm^2/s)	R_{i0}	Q_{s0} (g/s)	Q_{w0} (l/s)	D_s mm	Slope
6	15.0	10	4.3	0.645	0.31	120.0	10.50	0.03	0.05
7	20.0	10	7.5	1.508	0.30	280.0	14.00	0.03	0.05
8	20.0	10	8.3	1.663	0.34	300.0	14.00	0.03	0.05
9	27.0	8	6.9	1.482	0.12	250.0	15.00	0.04	0.05
10	27.0	8	4.3	0.920	0.08	170.0	15.00	0.04	0.05
13	27.0	8	4.1	0.887	0.07	164.6	15.00	0.03	0.05
14	27.0	8	5.0	1.087	0.09	200.0	15.00	0.03	0.05

Table 1. Inlet condition and other characteristics of the experiments Parker *et al.* (1987).

In Fig 9a of Garcia (1994) the author showed the results on the longitudinal velocity profiles distribution for 4 experiments, the main characteristics being summarized in Table 2. The velocity profiles referenced to the experiments in Table 2 are shown in Figure 4b, here presented for both the slope and the plain configuration.

The velocity profiles presented in the Figure 4 belong to supercritical sediment laden currents, which are performed on a slope of 0.05 for the experiments of Parker *et al.* (1987) and equal to 0.08 for the currents presented in the work of Garcia (1994). In our

Run	U_0 (cm/s)	h_0 (cm)	C_0 10^{-3}	Ψ_0 (cm^3/s^3)	R_{i0}	T_{in} (°C)	T_{fl} (°C)	Run time (min)
MIX1	13.3	3	3.64	234.8	0.10	17.0	16.5	45
MIX3	13.3	3	7.28	469.7	0.20	7.5	7.5	34
DEPO1	13.3	3	3.64	234.8	0.10	6.0	7.0	40
DEPO3	14.3	3	10.90	756.1	0.26	6.0	6.0	24

Table 2. Inlet condition and other characteristics of the experiments Garcia (1994).

experiment the longitudinal bed slope is only 0.005.
The size of the sediments used by Parker *et al.* (1987) are between 30μ and 40μ, and the mean grain size of the sediments employed in Garcia (1994) is $D_s = 27\mu$, while our silica flour has a mean grain size equal to 8μ.

In spite of the above mentioned differences, it is worth comparing the results of the previous authors with our experiments. In particular in Figure 5 we show the profiles recorded in section C4, C5 and C6 for experiment S25, compared with the previous datasets. It is possible to notice that the profiles are similar to the data obtained from the previous authors. However some differences arise. In particular the profiles obtained from our experimental observations show a value of the dimensionless velocity which is greater in the upper part, above the velocity maximum, and is lower in the region below the velocity peak. The reason for this differences may be due to the milder slope of the bed and/or to the presence of finer suspended sediment in our currents compared with the experiments of the previous authors. Indeed we have shown that sediments affects the velocity profiles moving down the velocity peak and increasing velocity in the lower region of the current.

In Garcia (1994) the author report the data of the subcritical currents that flow on the plain bed along the second reach of the flume. The author underline that the similarity of the profiles in this region is not good as in the supercritical region. However comparing this dataset with our experiment S23 (a subcritical sediment laden current), it is possible to notice (Figure 6) that our results are similar to Garcia's data.

We have included the experimental observations of Parker *et al.* (1987) and Garcia (1994) in Figure 6b (in the revised paper) showing that our results are indeed similar in spite of the quite low longitudinal bed slope of our experiment (S=0.005), much smaller than that corresponding to the above mentioned experiments (S=0.05 and S=0.08, respectively).

Comment 6) Data is reported on specific discharge variation along the flume, no water entrainment equation is applied to enhance the analysis. This is inconsistent along the manuscript: an equation is used to estimate the head velocity. I suggest the authors use equation 20 (reference a, Comment 1).

In Parker *et al.* (1987) the authors suggest a relation (their eq. 20) to estimate the entrainment coefficient that reads:

$$e_w = \frac{0.075}{(1 + 718\ Ri^{2.4})^{0.5}} \tag{1}$$

Such equation has been used employing the values of the Richardson number averaged over the straight reach. The values of e_w obtained from equation eq:ew has been compared with the experimental value of entrainment coefficient $\tilde{e}_w$ obtained calculating the average variation of flow discharge along the same straight reach. The comparison reported in Figure 7 shows that the empirical prediction of Parker *et al.* (1987) provides a good estimate of water entrainment. In Figure 7 the horizontal bars represent the root mean square associated with the spatial variability of the densimetric Froude number.

This figure and these comments have been included in the revised version of the

manuscript (lines 427-439).

Comment 7) Plot the interfaces in Figures 11a, 12 and 13a.

The interfaces have been added in figures 9a, 10 and 11a respectively in the revised version of the manuscript.

Comment 8) Figure 15: what is the cross-section? Same question for Figures 16 and 17.

For all these plot the data are acquired in the cross–section C5 located in the middle of the straight reach. This has been specified in the revised version of the manuscript.

Comment 9) Effect of excess density: The authors claim "in Fig. 16b the shape of the velocity profiles do not seem to be affected by this change" However (and near the bottom), profiles corresponding to S19 and S20 start around 0.9, while S18 starts with a value smaller than 0.6. Furthermore, S19 and S20 indicate a velocity reduction near the bed; S18 shows a continuous velocity increase in the same region. Why is that?

We employed an Ultrasound Doppler Velocimetry Profiler to acquire velocity data. In the region near the rigid bed (typically of the order of a few millimeters from the bed) the ultrasonic signal is affected by the presence of the bottom wall, hence results are not accurate. Hence, in the revised version of our manuscript, we have neglected that region in every plot reporting the longitudinal velocity above a threshold (2.5 mm from the bed). In Figure 8 we reproduce the Figure 16b of the paper; the velocity profiles refer to experiments S18, S19 and S20 measured in section C5.

Comment 10) Effect of the densimetric Froude #: I agree with the statement related to the lack of change of the dimensionless shape of the velocity profile as function of Frd. However, this is only true in the density current's body. Outside that area, the variation described in Figure 17 is significant. This, in turn, could play a key role in water entrainment.

We agree with the referee. This has been pointed out in the revised version of out manuscript (lines 703-731).

Please also note the supplement to this comment:
http://www.earth-surf-dynam-discuss.net/1/C658/2014/esurfd-1-C658-2014-supplement.pdf

Interactive comment on Earth Surf. Dynam. Discuss., 1, 817, 2013.

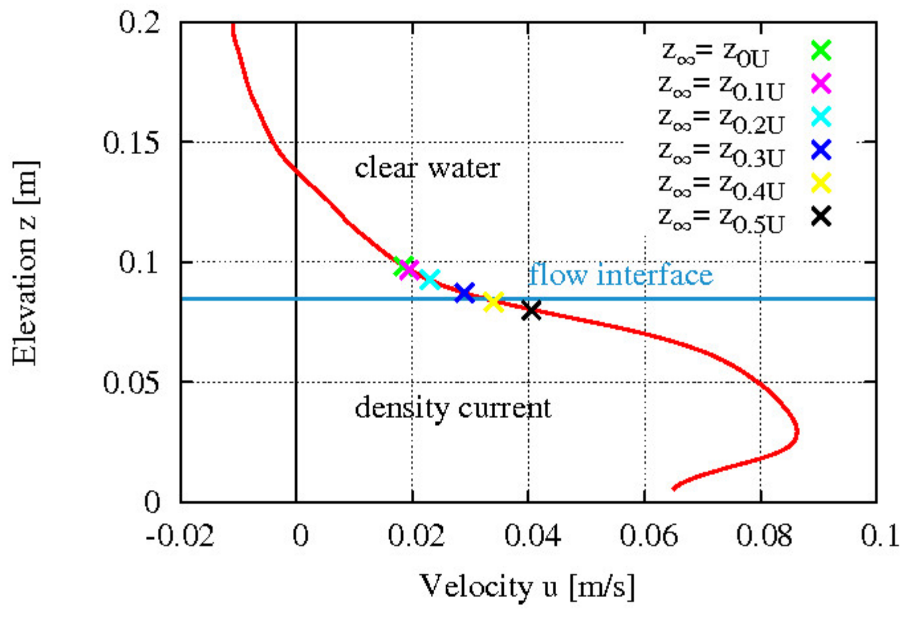

Fig. 1. Comparison between the computed flow height with different upper limit of integration (0-0.1-0.2-0.3-0.4-0.5U) and the visual flow interface (blue line)(Experiment S4 - section C5).

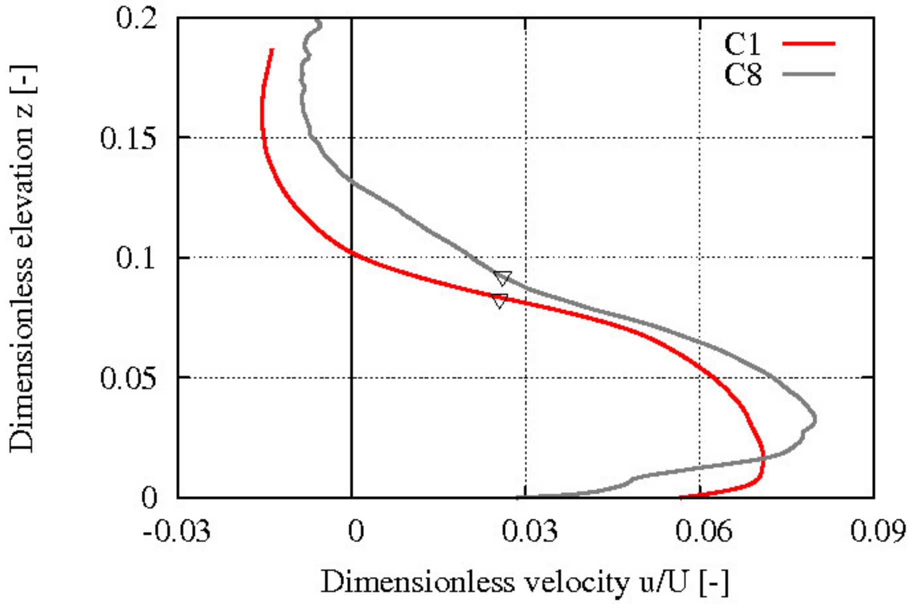

Fig. 2. Dimensional velocity profiles: comparison between the initial cross–section C1 and the section C8. The black triangles indicate the elevation of the flow interface.

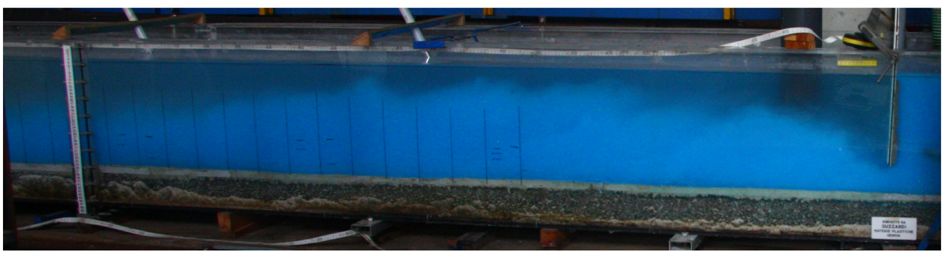

Fig. 3. Image of experiment S9. It can be seen on the right the inlet chamber, and the inlet section controlled by the sluice gate.

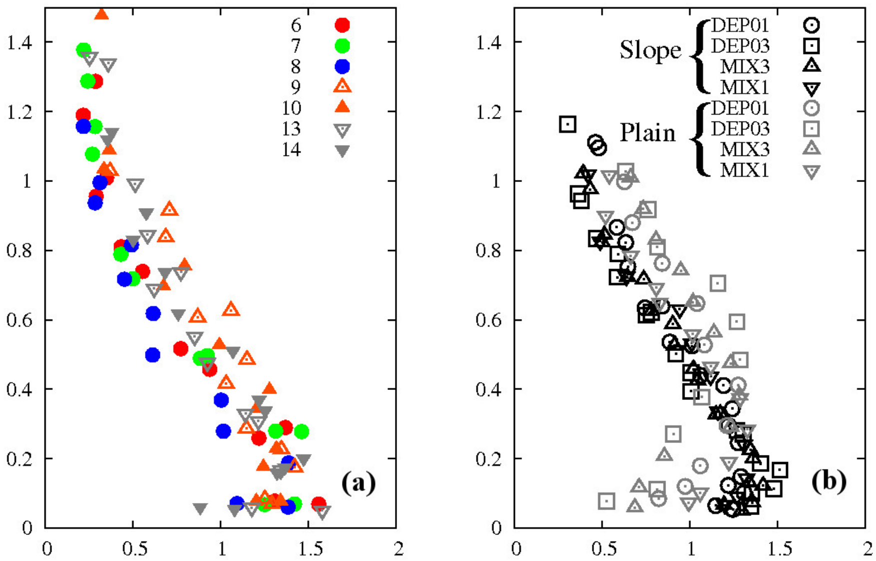

Fig. 4. Approximate similarity collapse for velocity using experimental data of (a) Parker \emph{et al.} (1987) and (b) Garcia (1994).

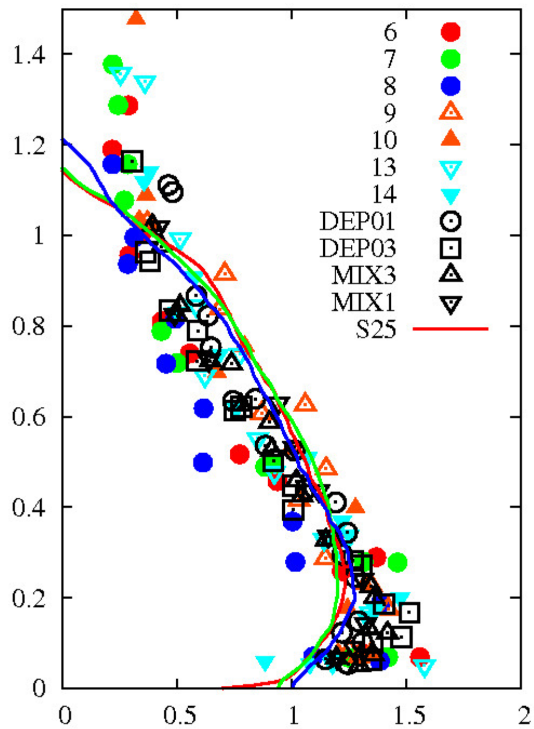

Fig. 5. Dimensionless velocity profiles: comparison between experimental results of Parker et al. (1987) and Garcia (1994) with our experimental results of exp. S25 measured in section C4, C5 and C6.

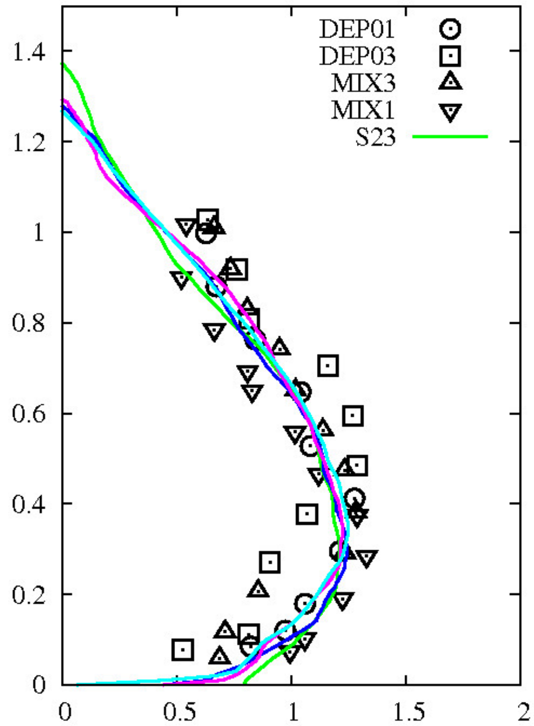

Fig. 6. Dimensionless velocity profiles: comparison between experiments by Garcia (1994) in the subcritical region of the flume (plain bed) and our experimental results for exp. S23, sections from C4 to C8.

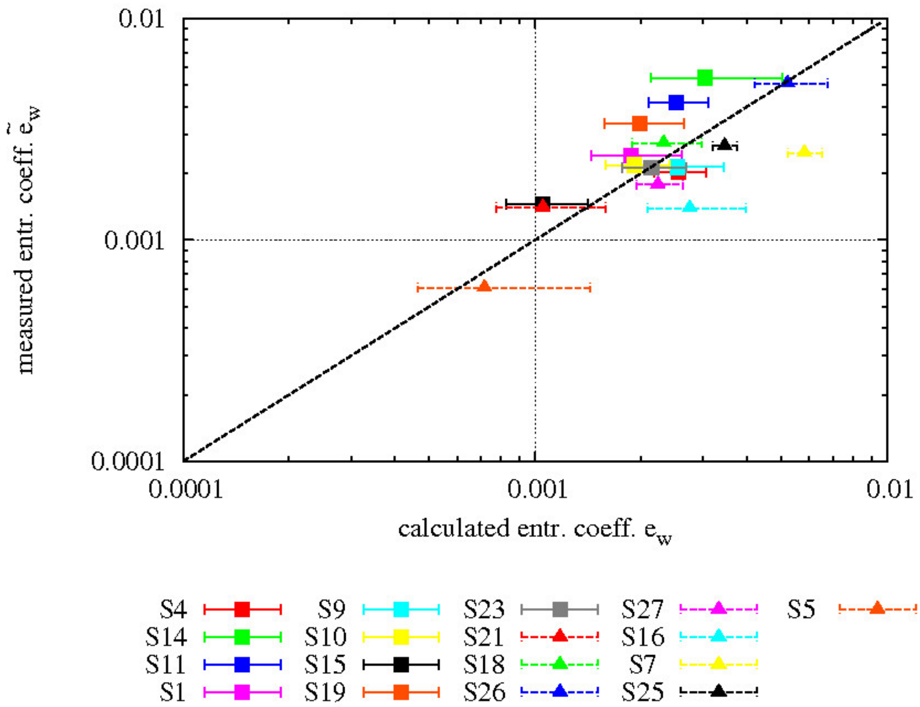

Fig. 7. Comparison between the measured experimental value of entrainment coefficient $\tilde{e}_w$ and the calculated value of e_w obtained from the relation proposed by Parker et al.(1987).

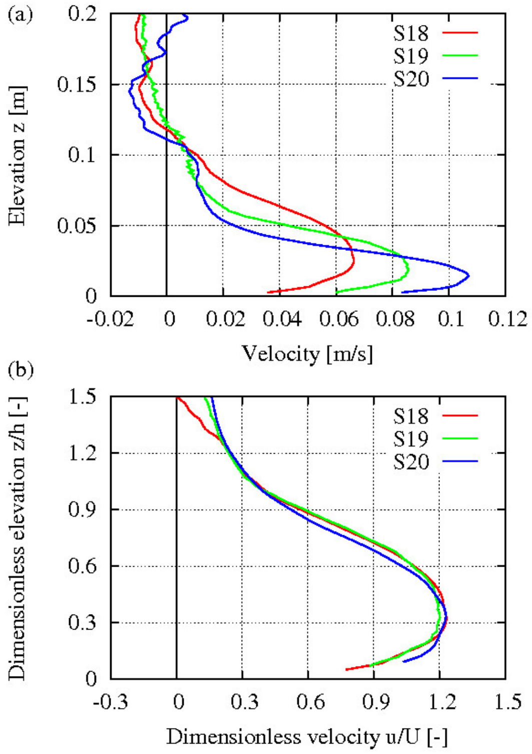

Fig. 8. Dimensional (a) and dimensionless (b) comparison between density current velocity profiles with different density excess ($\Delta\rho/\rho$) and same flow discharge ($q_0=0.0026$ m^2/s) at the inlet.