Time evolving bed shear stress due the passage of gravity currents estimated with ADVP velocity measurements
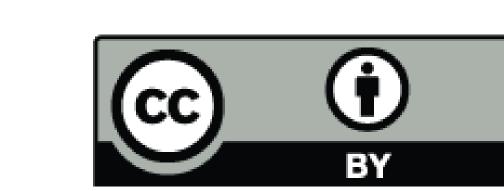
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Method

- **Gravity current** reproduced under controlled **laboratory** conditions.
- High resolution **3D instantaneous velocity measurements** acquired with the non-intrusive Acoustic Doppler Velocity Profiler (**ADVP**) [4].
- Analysis of the **turbulence structure** of a gravity current
- Evaluation of the spatial evolution of **bed shear stress** at the passage of the gravity current.

Introduction

Gravity currents are buoyancy driven flows that occur, naturally or as a consequence of human activities, due to temperature differences, dissolved substances or to the presence of particles in suspension [1]. The currents are performed in a specifically designed channel that, through the lock-exchange technique [2], create saline gravity currents. The study of the inner mechanisms of these currents are of fundamental importance since the highly turbulent behaviour is not yet completely revealed. In particular, the majority of the turbulence production comes from the shear at the bottom. This quantity can be linked to the erosive capacity and deposition mechanisms of a gravity current passing on a mobile bed.

TEST	$\rho_c \left[\frac{kg}{m^3}\right]$	$\gamma \, [-]$	$g_0 \left[\frac{m}{s^2}\right]$	$Fr_b \, [-]$	$Re_0 \, [-]$
S3	1040	0.96	0.39	0.137	55961
S4	1048	0.95	0.46	0.157	60884

Table 1: Experimental parameters for the two tests.
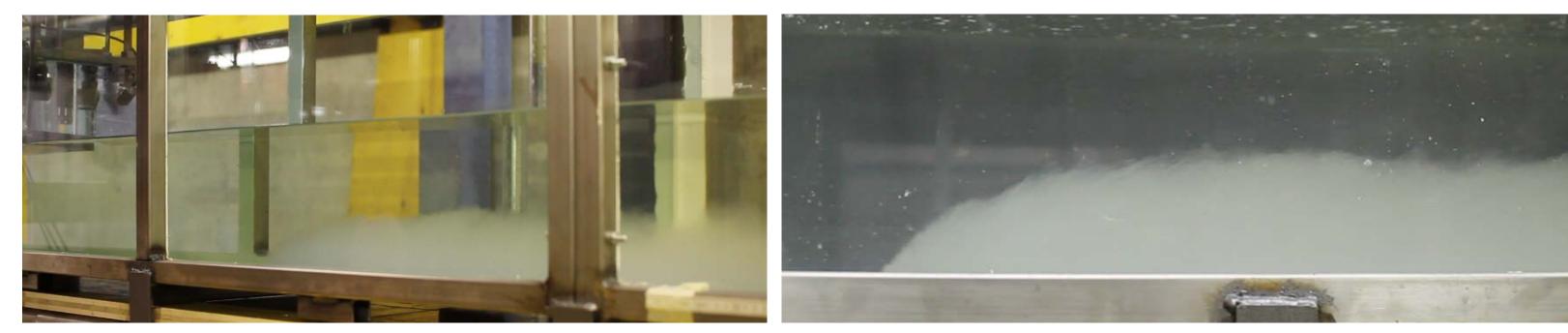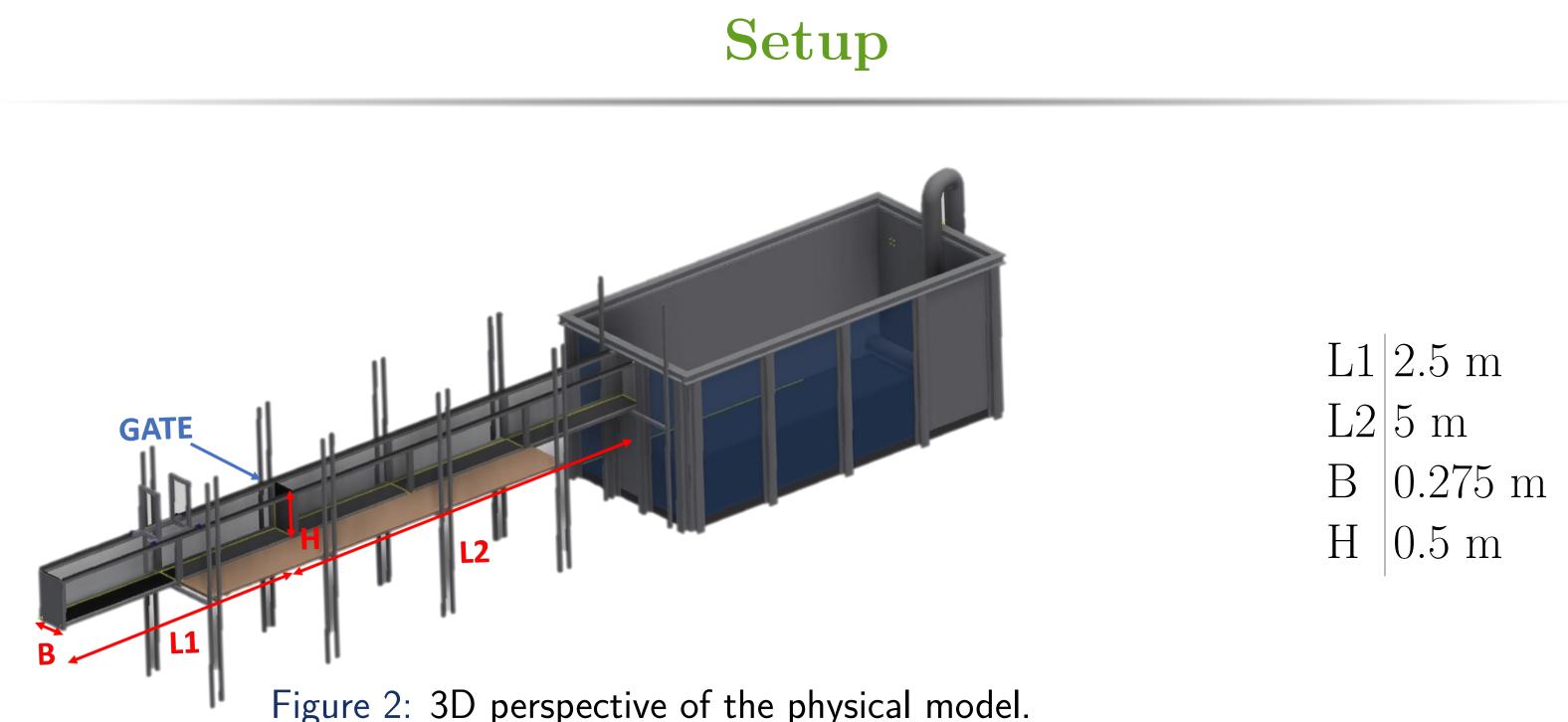
Figure 1: Experimental set-up at LCH (EPF Lausanne).

Setup

L1	2.5 m
L2	5 m
B	0.275 m
H	0.5 m

Figure 2: 3D perspective of the physical model.

Procedure

The tests were prepared according to the steps outlined below:

1. The channel is filled with clear water (water depth of 0.2 m)
2. A certain amount of **salt** is added in the head tank to reach the initial density wanted
3. The **ADVP** is turned on and acquires high-resolution velocity measurements along the vertical
4. The **gate** is abruptly opened letting the fluids of different densities getting in contact
5. The **underflow gravity current** forms

Important Result

Instantaneous longitudinal velocity fields are derived from the velocity measurements collected with the ADVP. Detailed velocity profiles are the base for the estimation of the bottom shear stress through the logarithmic law of the wall [3]. Bottom shear stress is linked to the erosive and depositive capacity of the gravity current.

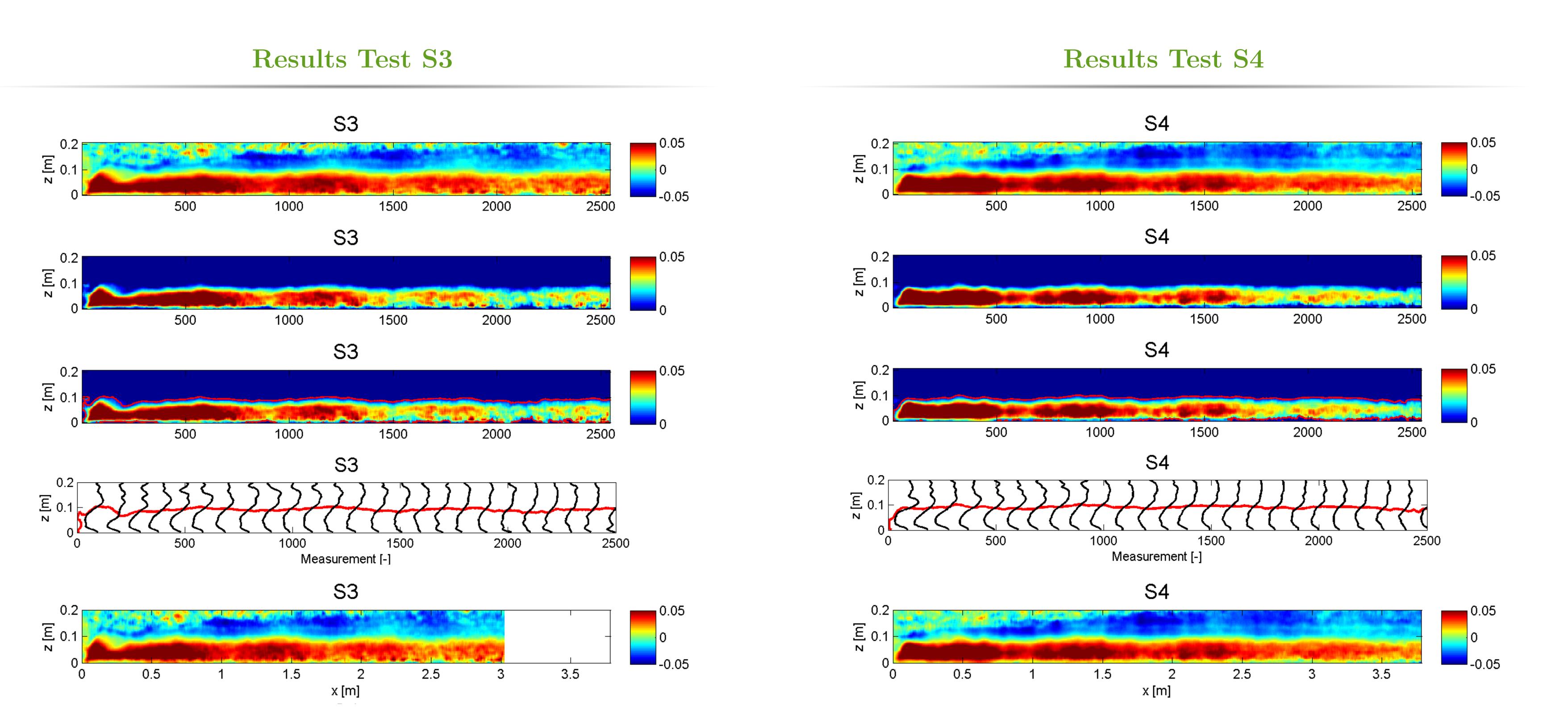## Results Test S3

Results Test S4

Figure 3: Instantaneous longitudinal velocity field (m/s) for the tests S3 and S4. The data are then treated in order to identify the boundary of the current passing through the isolation of the positive values of velocity (hiding the counter current created by the ambient fluid). Some of the vertical profiles are plotted together with the contour of the currents. These series of profiles are used to compute the bed shear velocity (through the log-law) for the estimation of bed shear stress. In the final plot, to allow for a spatial visualization of the different regions composing the current, i.e. head, body and tail, and to relate these with the bed shear stress, the information in time is converted into space. This is done by considering a constant advection velocity equal to the front velocity.

Bed shear stress

The equation of the **logarithmic law of the wall** allows the calculation of the bed shear velocity through a fitting procedure of the law at the experimental velocity profiles. The **fitting procedure** is adopted for each instantaneous profile collected with the ADVP instrumentation zone-averaged over a window enough long. The red line indicates the **bed shear stress** calculated for each instantaneous profile.
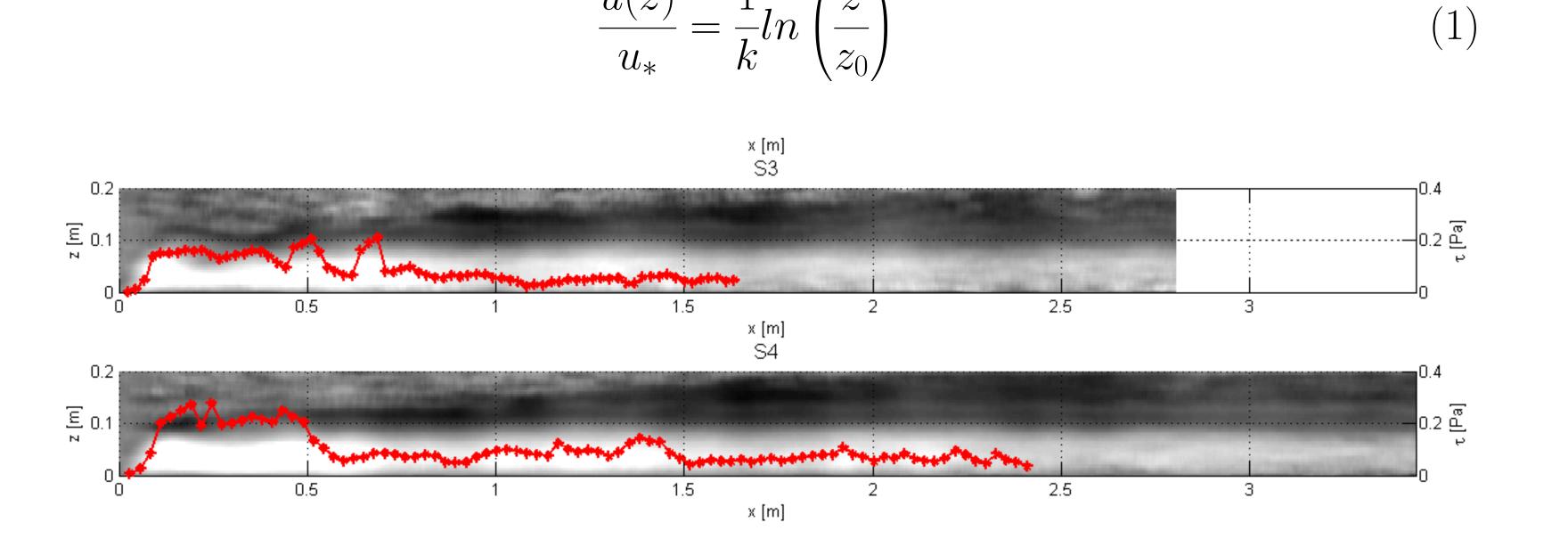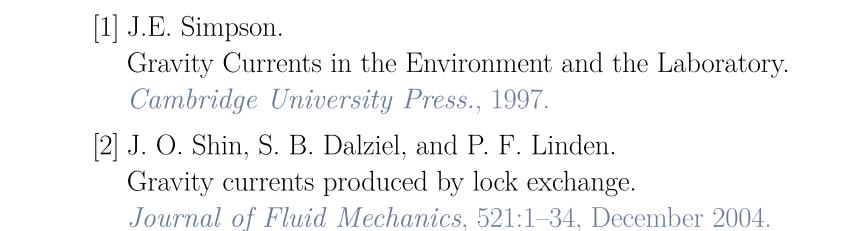
$$\frac{u(z)}{u_*} = \frac{1}{k} ln\left(\frac{z}{z_0}\right) \qquad (1)$$

Figure 4: Bed shear stress evolution computed after the fitting procedure of the log layer.

Discussion

These preliminary tests show that, with the 3D ADVP velocity measurements, the evolution in time of the channel-bed shear stress due the passage of gravity currents may be estimated. Further studies are planned investigating the relation of the bed shear stress with the erosion processes and with the dynamics of the current.

References

[1] J.E. Simpson. Gravity Currents in the Environment and the Laboratory. *Cambridge University Press.*, 1997.

[2] J. O. Shin, S. B. Dalziel, and P. F. Linden. Gravity currents produced by lock exchange. *Journal of Fluid Mechanics*, 521:1–34, December 2004.

[3] R.M.L. Ferreira, M.J. Franca, J.G.A.B. Leal, and A.H. Cardoso. Flow over rough mobile beds: Friction factor and vertical distribution of the longitudinal mean velocity. *Water Resources Research*, 48(5):1–14, 2012.

[4] T. Rolland and U. Lemmin. A two-component acoustic velocity profiler for use in turbulent open-channel flow. *Journal of Hydraulic Research*, 35(4):545–562, July 1997.

Acknowledgements

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