Interaction of gravity currents with slopes and overhangs

Maria Rita Maggi YP[1*], Claudia Adduce[1], Gregory Francis Lane-Serff2

1Roma Tre University, Rome, Italy; 2University of Manchester, Manchester, United Kingdom

*Correspondence YP: mariarita.maggi@uniroma3.it

Abstract The dynamics of the gravity currents interacting with sloping and overhanging barrier are investigated by laboratory experiments. Gravity currents are generated in a Perspex tank and an image analysis technique is applied to evaluate the instantaneous density fields. A wide range of slope angles are tested. The position of the incoming gravity currents and outgoing bores for flows reflected is evaluated and discussed. The analysis performed shows how a complex topography strongly affects the dynamics of the dense current and, consequently, emphasizes a more articulated dynamic in the overhangs cases.

Keywords: gravity currents, stratified flows, complex topography.

Methods

All the experiments are conducted in a Perspex tank using an experimental set-up similar to the one described in Lane-Serff et al. (1995) (Fig.1). The lock region was filled with salty water at density ρ_1 while the rest of the tank with ambient fluid at density ρ_0 ($\Delta\rho = \rho_1 - \rho_0 = 40\,kg/m^3$).

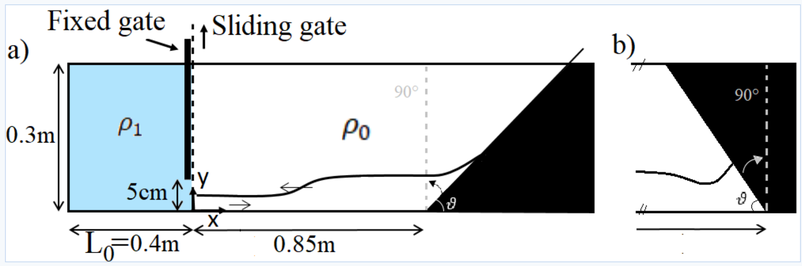

Fig.1: *Sketch of the tank used to perform laboratory experiments respectively a) slope and b) overhang barrier cases.*

The instantaneous front position and the reflected bore position were studied by the instantaneous width averaged density field, $\rho^* = \frac{\rho(x,y,t)-\rho_0}{\rho_1-\rho_0}$, obtained trough a pixel based image analysis technique.

The experimental front position is defined by using the non-dimensional iso-density contours at $\rho^* = 2\%$, while the reflected current position is defined adopting the non-dimensional iso-density contours at $\rho^* = 50\%$ (Fig.2).

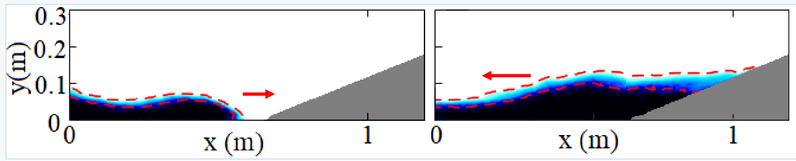

Fig.2: *Non dimensional density fields of laboratory experiments.*

Results

The dimensionless front/outgoing bore position, $x^* = x/L_0$, versus the dimensionless time, $t^* = t/t_0$, for the Up-Slope cases and the Overhangs cases are shown in Fig.3.

In the Up-Slope cases (Fig.3a), the current is characterized by a constant front speed until it reaches the slope (red line) where it starts to decelerate as it flows up the slope while a reflected bore propagates back upstream. A negative correlation is observed between the slope angle ϑ and the start time of reflection.

In the Overhang case (Fig.3b), the current decelerates as it approaches the foot of the barrier being affected by its presence. In this case the reflection starts in a close range of time for all the experiments regardless of the value of ϑ.

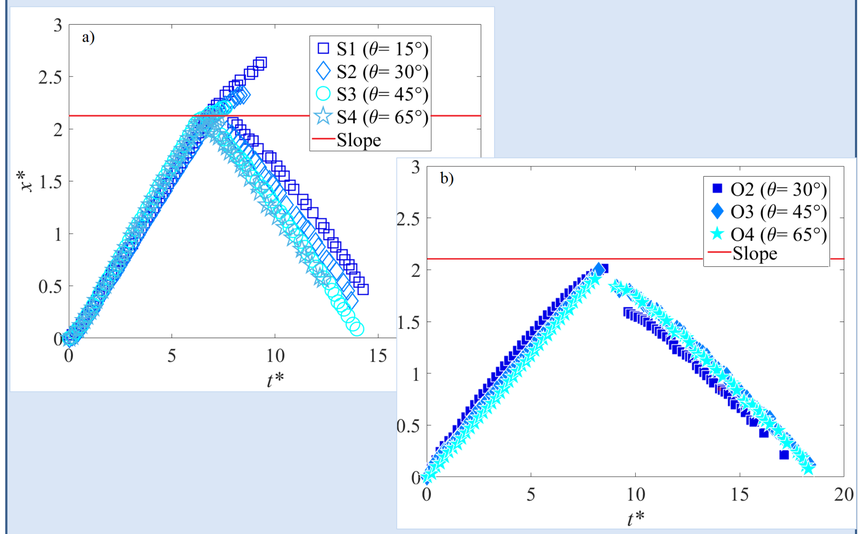

Fig.3: *The dimensionless front position and outgoing bores for flows reflected from Up-Slopes a) and Overhangs b).*

Conclusions

The aim of this study was to investigate how topographic features of the domain affect the dynamics of the gravity current.

Despite the initial development of the current exhibiting a similar behavior for both cases, when the dense flow approaches the barrier, the deceleration of the current is greater in the Overhang case than in the Up-Slope. As a consequence, the reverse flow presents a quite different behaviour. Furthermore, the density fields analysis emphasizes a more complex dynamics in the Overhangs cases related to the presence of the barrier.

Bibliography

De Falco, M.C., Ottolenghi, L., Adduce, C. Dynamics of gravity currents flowing up a slope and implications for the entrainment. *J. Hydraul. Eng.*, 46(6), 04020011.

Inghilesi R., Adduce C., Lombardi V., Roman F., Armenio V. (2018). Axisymmetric three-dimensionl gravity currents generated by lock exchange. *J. Fluid Mech*., 851, 507–544.

Lane-Serff, G.F., Beal, L.M., Hadfield, T. (1995). Gravity current flow over obstacles. *J. Fluid Mech*., 292, 39–53.

Ottolenghi, L., Prestininzi, P., Montessori, A., Adduce, C., and La Rocca, M. (2018). Lattice Boltzmann simulations of gravity currents. *Eur. J. Mech*., 67, 125–136.

Simpson, J.E., and Manga, M. (1998). Gravity current in the environment and the laboratory. *Phys. Today*, 51(4), 63.

1st IAHR Young Professionals Congress (17-18 November 2020)