DNS/LES OF PARTICLE-DRIVEN GRAVITY CURRENTS IN A BASIN CONFIGURATION

R.A.S. Frantz[1], E.P. Francisco[1], S. Laizet[2] &J.H. Silvestrini[1]
[1]*Faculdade de Engenharia, Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre - RS, Brasil*
[2]*Turbulence, Mixing and Flow Control Group, Department of Aeronautics, Imperial College, London, United Kingdom*

Gravity currents are common phenomena in nature and occur when fluid with different density come into contact in the presence of gravity. This work compares three-dimensional Direct and Large Numerical Simulations (DNS/LES) of gravity currents in a basin configuration generated for open and closed computational domains. Open domains are designed to produce quasi-steady currents whereas closed domains are designed to produce surge-like flows. The incompressible Navier-Stokes equations and a scalar transport equation under the Boussinesq approximation for the particles are solved on a Cartesian mesh with the high-order flow solver **Incompact3d**. It is based on sixth-order compact schemes for spatial discretization and a third order Adams-Bashforth scheme for time integration [3]. The effect of the non-resolved small-scale structures in the LES is dealt with targeted numerical dissipation introduced by the discretization of the viscous term in the Navier-Stokes equations [4]. A computational domain with dimensions $L_1, L_2, L_3 = 12, 2, 12$ is discretized, for the DNS, with $n_1, n_2, n_3 = 1201, 289, 1201$ points. Note that the cost of the LES is about 15% of the cost of the DNS.

In the studied basin configuration, the flow can freely evolve in the streamwise and spanwise directions. It is different from a more conventional channelized set-up for which the current is constrained in the spanwise direction. For the particles sedimentation in the vertical direction, a simple outflow boundary condition is imposed at the bottom of the domain to mimic the deposition process. For the closed domain set-up, there is a gate separating the initial finite-volume of particles from the clear fluid. When the gate is removed, the flow quickly expands to give rise to a current with a rounded tongue shape as seen in figure 1. For the open domain set-up, inflow/outflow boundary conditions allow the investigation of finite and continuous release of particles. More details about the present open domain set-up can be found in [2]. Figure 1 compares particle concentration footprints at the bottom of the domain (with isolines of 0.1%) obtained at $Re = 5000$, at an advanced simulation stage, resulting from the highly turbulent dynamics of the flow. It can be seen that the lobe-and-cleft structures are forming at an earlier time for the closed domain set-up.

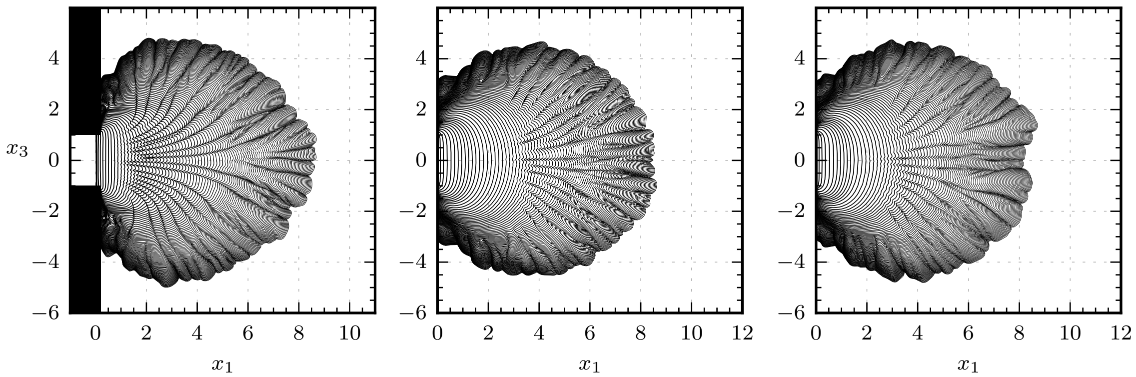

Figure 1. Concentration footprint in a DNS closed domain set-up (left) and in an DNS (centre) and LES (right) open domain set-up.

The present investigation aims to understand better if our LES can capture the spatiotemporal evolution of a gravity current in a basin configuration for an open domain set-up. Based on preliminary results, it seems that it is possible by means of DNS to recover the main features observed in the closed domain set-up. Moreover, despite a drastic computational cost reduction, the LES in an open domain set-up is also giving very satisfactory results even especially with the correct reproduction of the main features of the lobe-and-clefs structures at the front of the current. This analysis will be extended to different Reynolds numbers to investigate the quality of our LES and to identify differences in the flow structures and dynamics, with respect to DNS. The focus will be a comparison between the temporal evolution of the front location, the suspended mass and sedimentation rate, and the deposition pattern on the bottom of the domain which is strongly dependent on the lobe-and-cleft structures at the front of the current [1].

References

[1] L. F. R. Espath, L. C. Pinto, S. Laizet, and J. H. Silvestrini. High-fidelity simulations of the lobe-and-cleft structures and the deposition map in particle-driven gravity currents. *Physics of Fluids*, **27**(5):056604, 2015.

[2] R. A. S. Fratnz, S. Laizet, and J. H. Silvestrini. Direct numerical simulation of hyperpycnal flows in open-channel configuration. In *10th ABCM Spring School on Transition and Turbulence*, page 9, Sao Jose dos Campos, Brazil, 2016.

[3] S. Laizet and E. Lamballais. High-order compact schemes for incompressible flows: A simple and efficient method with the quasi-spectral accuracy. *J. Comp. Phys.*, **228**:5989–6015, 2009.

[4] E. Lamballais, V. Fortune, and S. Laizet. Straightforward high-order numerical dissipation via the viscous term for direct and large eddy simulation. *J. Comp. Phys.*, **230(9)**:3270–3275, 2011.