Development Processes of Turbidity Currents Toward the Equilibrium State: Examination by Numerical Simulation

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In this study, development processes of turbidity currents toward the equilibrium state was investigated by the numerical simulation using the renormalized group k-epsilon turbulence model. Turbidity currents are particle-laden currents driven by gravity, which occur in deep seas and lakes. It has been indicated that turbidity currents run out over tens to hundreds of kilometers and deposit vast amounts of sediments on submarine fans of deep sea floors. Existing layer-averaged numerical models of turbidity currents, however, cannot reproduce such long-traveled turbidity currents because the flows entrain the ambient water and get diluted as they run down. Recently, Luchi et al. (2015) developed the vertically resolved k-epsilon model of turbidity currents in the steady condition, and implied that turbidity currents become bipartite at the horizon showing the maximum flow velocity. Their model indicated that the upper parts of turbidity currents get rarified as they run down, whereas the lower parts which carry most of the suspended sediment have the equilibrium state, which can be sustained over long distances without any dilution and deceleration. Although this model might explain the reason why turbidity currents can run out for long distances, their model assumed the steady state, so that it was not explained whether the flows can reach the equilibrium state within realistic spatio-temporal scale in the actual sedimentary environments.

Therefore, this study focuses on the processes of both temporal and spatial developments of turbidity currents to become the equilibrium state. This study conducted the two-dimensional numerical simulations using computational fluid dynamics software FLOW-3D in order to obtain spatio-temporal change of flow properties of turbidity currents in both vertical and flow-parallel directions. The simulation was conducted under the condition at which the turbidity current continued flowing from the upstream end of the computational domain at constant rates of velocity and sediment concentration for a given time. The computational domain was 200 m long and 30 m deep, and the computational grid size was 5 cm for both vertical and horizontal directions. The flow velocity and height at the upstream boundary were respectively fixed to the values 1 m/s and 0.5 m, and the experimental duration was set to 1800 seconds. As a result of simulation, we obtained the following findings: (1) the turbidity current reached the steady state about several minutes after the beginning of simulation, (2) the height of the horizon showing the maximum velocity was constant in the region about 4 m from the inlet to the downstream end, (3) the maximum velocity converged to the constant value at about 150 m from the inlet, and (4) the flow height defined by the inflection point of the flow velocity profile continuously increased downstream. These results suggest that the lower part of the turbidity current reached the equilibrium state within about 150 meters at the given experimental condition, whereas the upper part of the flow remained non-uniform because of entrainment of the ambient water. Although further numerical simulations at various experimental conditions are required to conclude, we tentatively infer that the lower part of turbidity currents at natural scale can easily reach the equilibrium state and the upper part continues being rarified. In the future, this study will lead to the development of a new layer-averaged model of two-layered turbidity currents which can solve the large-scale morphodynamic problems.

Reference

Luchi, R., Parker, G., Balachandar, S., and Naito, K. (2015). Mechanism governing continuous long-runout turbidity currents (in Japanese with English abstract). *Journal of Japan Society of Civil Engineers, Ser. B1 (Hydraulic Engineering)*, 71.

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