Cyclic steps formed by long-runout turbidity currents

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It has been found that a variety of submarine morphology such as submarine fans, submarine rivers, and submarine canyons, has been formed by turbidity currents which travel relatively long distance (long-run out turbidity currents). The long-run out turbidity currents have a number of features similar to open channel flow. They have an equilibrium (or quasi-equilibrium at least) state, and are accompanied by hydraulic jumps when they transition from supercritical to subcritical flow regimes. In this research, with the use of the assumption that an equilibrium state can be achieved in the high-concentrated lower layer near the bottom of long-run out turbidity currents, we propose an analytical model with the use of the layer-averaged governing equations, which reproduces cyclic steps with relatively long wavelengths accompanied by periodic internal hydraulic jumps.

Integrating the Reynolds-averaged Navier-Stokes equations and continuity equation over the high concentrated lower layer, we obtain the boundary layer approximated (layer-averaged) momentum and continuity equations. In the integration, it is possible to simplify the governing equations by ignoring the entertainment from the top of the high concentrated lower layer with the assumption that the Reynolds stress becomes almost zero and the shear stress almost vanishes there. In addition to the momentum equations and continuity equation, we employ the diffusion/dispersion equation of suspended sediment, and the continuity equation of sediment (Exner equation).

The unknown variables in the problem are four: the velocity, the layer thickness, the layer-averaged suspended sediment concentration, and the bed elevation. The governing equations are the layer-averaged momentum and continuity equations, the layer-averaged diffusion/dispersion equation of suspended sediment, and the continuity equation of sediment (Exner equation). The boundary conditions for this problem are that the momentum has to be continuous before and after each hydraulic jump. More specifically, the velocity and the layer thickness have to satisfy the jump condition before and after each jump. In addition, the suspended sediment concentration has to be continuous at the jump.

We solve the problem numerically, and obtain the wavelengths of steps. The wavelength of a long-run out turbidity current is determined by the thickness of the high-concentration layer near the bottom. It is shown that the wavelengths obtained in the analysis agree relatively well with the observation.

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