Numerical simulations of cyclic steps formed by turbidity currents

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Turbidity currents, which are a sediment-laden density current flowing in water over a bed surface, form a variety of subaqueous landscapes due to the complex interactions among flow, sediment transport and morphodynamic processes. This study specifically focuses on the formation and development of subaqueous cyclic steps due to turbidity currents. Cyclic steps are a common morphodynamic feature of seascapes, and are generally found on continental shelf and slope. These field evidences suggest that the turbidity current flowing over continental margin is a main driver of developing the cyclic steps. The dynamics of cyclic steps have been thoroughly investigated by field observations and laboratory experiments and there are several mathematical and numerical models to reproduce turbidity current and subsequent formation of cyclic steps. Layer-averaged model of turbidity currents has been widely used to model the cyclic step dynamics although this type of models is a rather simple to capture full dynamics of phenomena, especially, complex hydrodynamics over cyclic steps. On the other hand, high resolution fluid dynamic models such as Reynolds averaged Navier Stokes (RANS) model, large eddy simulation (LES), and Direct Numerical Simulation (DES) have successfully captured the complex hydrodynamics and sediment transport due to the turbidity currents. But such approaches are computationally expensive to pursue cyclic step dynamics which is much longer morphodynamic phenomena than a flow. In this study, we attempt to numerically reproduce the dynamics of turbidity current and subsequent cyclic step formation using a depth-resolved RANS model.
The flow model we use in this study is an unsteady Reynolds averaged Navier Stokes model. This type of model has been well validated and calibrated to reproduce the turbidity current dynamics, and possibly track a morphodynamics of cyclic steps induced by turbidity currents within reasonable computational time. The flow model is then coupled with the advection-diffusion equation of suspended sediment and dissolved salt, which are the driving forces of the flow. We apply the model to small scale, idealized flumes to understand the model performances for reproducing the cyclic steps. The results show that the model can reasonably capture the formation of cyclic steps by a turbidity current, and their migration toward upstream direction. We have then performed a sensitivity analysis of simulated characteristics of cyclic steps to the model parameters. In particular, effects of boundary conditions on the cyclic step formation is investigated. For this, we imposed several types of turbidity currents (e.g., continuous or surge-type) to upstream boundary, and see how these factors affect the dynamics of cyclic steps.

キーワード：サイクリックステップ、混濁流、数値計算
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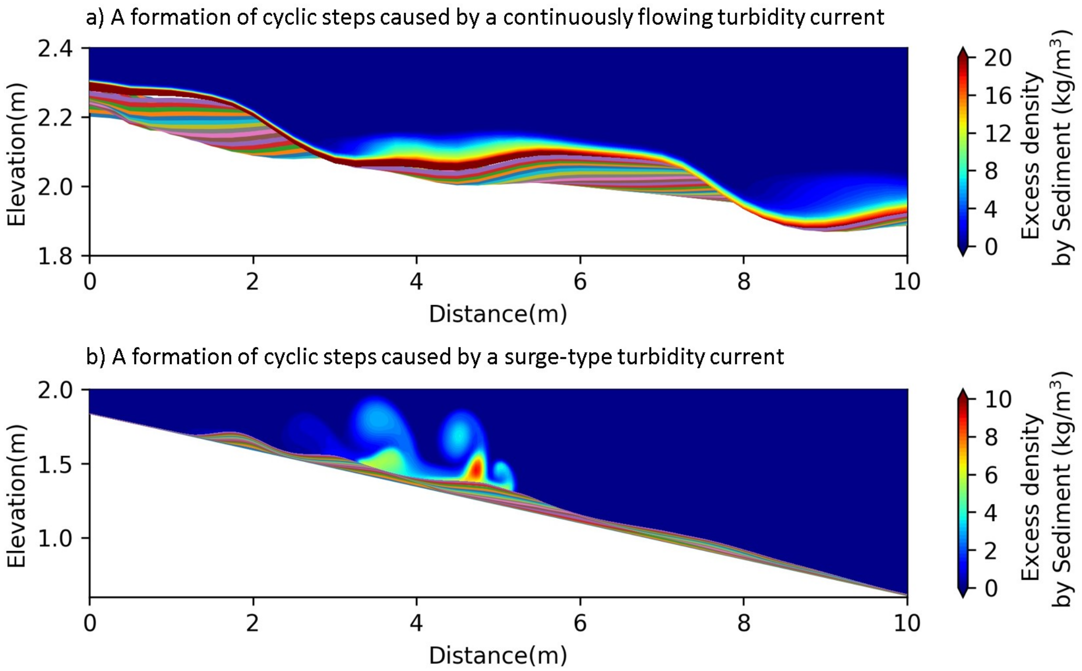
a) A formation of cyclic steps caused by a continuously flowing turbidity current
Elevation(m)
Distance(m)
Excess density by Sediment (kg/m³)
b) A formation of cyclic steps caused by a surge-type turbidity current
Elevation(m)
Distance(m)
Excess density by Sediment (kg/m³)