

Interaction of suspended sediment and salt wedge in a river estuary

Tokuzo Hosoyamada¹, Ayurzana Badarch² and Takeshi Ohtake²

¹ Department of Civil and Environmental Engineering
Nagaoka University of Technology, 1603-1, Kamitomioka Nagaoka Niigata Japan, 940-2188
E-mail: rng@nagaoka.ut.ac.jp

² Graduate School of Energy and Environmental Eng., Nagaoka University of Technology,
1603-1, Kamitomioka, Nagaoka, Niigata, Japan, 940-2188

³ Graduate School of Civil Engineering, Nagaoka University of Technology,
1603-1, Kamitomioka, Nagaoka, Niigata, Japan, 940-2188

Estuarine turbidity maximums (ETM) are observed at the frontal zone between the fresh and saline waters in macrotidal estuary. Strong mixing process and interaction of sediment and salt wedge intrusion are supposed to make an influence on resuspension of sediment and turbidity transport. To understand the phenomena, the paper studies dynamics of the gravity head of salt wedge and its effects to sediment transport by means of numerical simulation based on Navier Stokes equation directly. Settling and resuspending flux at the riverbed is estimated by an empirical formulation. Effects of the gravity head reveal themselves remarkably in temporal development of velocity vectors, transport of suspended sediment, density deviation. Numerical results for total amount of sediment and vertical flux for resuspension and sedimentation are discussed.

Introduction

Estuaries act in a sense as a link between the limnetic and marine environments. One typical and very important region in estuary is the frontal zone between the fresh and saline water. In many estuaries, the front is characterized by salt wedge moving almost horizontally on a riverbed. The fluctuating flow fields caused by density difference may trigger resuspension of sediment and a peak of sediment concentration (estuarine turbidity maximum, ETM) on salt wedge (Burchard and Baumert, 1998).

The mechanics of density driven currents has been studied for a long time (Simpson and Britter, 1979). The research field is extending to so many fields such as volcanic dynamics, atmospheric dynamics for a macroscopic point of view, and chemical engineering for a microscopic point of view. Sediment and turbidity transport are studied in the field of river and coastal engineering. It is well known that the dynamics in estuary is characterized by a variety of complicated processes. Transport of suspended sediment or various elements of chemical substances in river flow are supposed to be influenced by salt wedge.

To understand such complicated processes (sediment and density transport together) by numerical simulation, the numerical scheme should be directory based on Navier-Stokes equation (NS eq.), which is essential of fluid dynamics. In this study, numerical results of density and sediment distribution and characteristics of fluid motion will be discussed.

Numerical methods

Governing equations for the unknown variables (velocities, pressure, sediments transport and density fluctuation) are incompressible continuity equation, NS eqs. and advection diffusion equations, which are shown in eq.(1),eq.(2), eq.(3) and eq.(4), respectively.

$$\frac{\partial u_i}{\partial x_i} = 0 \quad (1)$$

$$\frac{\partial u_i}{\partial t} + u_m \frac{\partial u_i}{\partial x_m} = -(1 + \frac{\Delta \rho}{\rho}) g \delta_{i2} - \frac{1}{\rho} \frac{\partial p}{\partial x_i} + \gamma_t \nabla^2 u_i \quad i = 1, 2 \quad (2)$$

$$\frac{\partial \Delta \rho}{\partial t} + u_m \frac{\partial \Delta \rho}{\partial x_m} = D \nabla^2 \Delta \rho \quad (3)$$

$$\frac{\partial c}{\partial t} + u_1 \frac{\partial c}{\partial x_1} + (u_2 - w_s) \frac{\partial c}{\partial x_2} = D \nabla^2 c \quad (4)$$

Here, $i, u_i, t, x_i, g, \rho, \Delta \rho, p, t, c, w_s$ are suffix for vector components, $i (=1,2)$ component of velocity vectors, time, spatial coordinate for i direction, gravity acceleration, average density, density deviation, pressure, effective viscosity (turbulent and molecular), sediment concentration and sediment settling velocity. Temporal development of velocity vectors is calculated by integration of NS equation directly. To satisfy incompressible continuity condition, pressure-velocity simultaneous relaxation scheme, which is refereed as SOLA method (Hirt, 1975) is used. Large eddy simulation

with Smagorinsky eddy viscosity model is used. Erosion flux and sedimentation flux through the riverbed are estimated as function of the bottom shear stress, critical shear stress and total amount of material for sediment.

Numerical results

Fig. 1. shows typical distribution of sediment, density, vorticity and vertical velocity. Sediment distribution has very high values at the top of the salt wedge, which is caused by high upper ward vertical velocity shown in Fig. 1 (vertical velocity). Interface between salt water and river water has wavy pattern. In pure water (upper part), horizontal velocity is higher than salt wedge and opposite direction to salt wedge (lower). In the interface of such region, the Kelvin-Helmholtz type instability occurs and vortex train is formed. In the paper, interaction of sediment and salt wedge, effects of surface water elevation to salt wedge will be discussed.

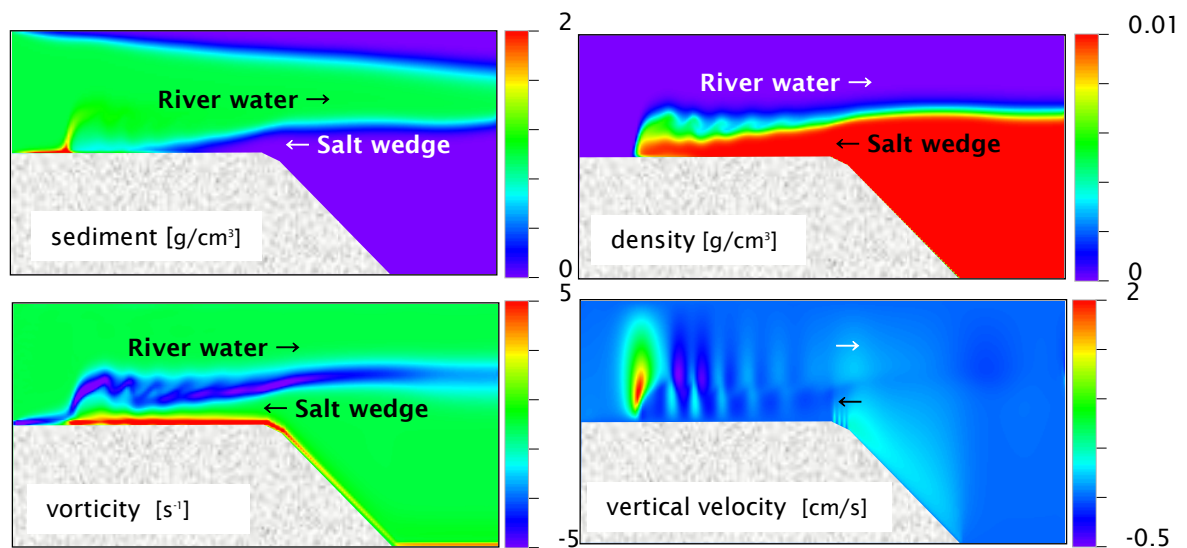


Fig. 1. Typical distribution of sediment, density, vorticity and vertical velocity

References

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