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On a Shallow Water Model for the Simulation of Turbidity Currents

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Abstract. We present a model for hyperpycnal plumes or turbidity currents that takes into account the interaction between the turbidity current and the bottom, considering deposition and erosion effects as well as solid transport of particles at the bed load due to the current. Water entrainment from the ambient water in which the turbidity current plunges is also considered. Motion of ambient water is neglected and the rigid lid assumption is considered. The model is obtained as a depth-average system of equations under the shallow water hypothesis describing the balance of fluid mass, sediment mass and mean flow. The character of the system is analyzed and numerical simulations are carried out using finite volume schemes and path-conservative Roe schemes.

AMS subject classifications: 74S10, 35L60, 35L65, 74G15

Key words: Turbidity currents, hyperbolic systems, finite volume methods, path-conservative schemes, numerical modeling.

1 Introduction

When a river contains an elevated concentration of suspended sediment, to the extent that the river density is greater than that of the receiving water body, the river can plunge and create a hyperpycnal plume or turbidity current. This hyperpycnal plume can travel significant distances until it loses its identity by entraining surrounding ambient water and dropping its sediment load. A sketch of a turbid underflow is presented in Fig. 1.

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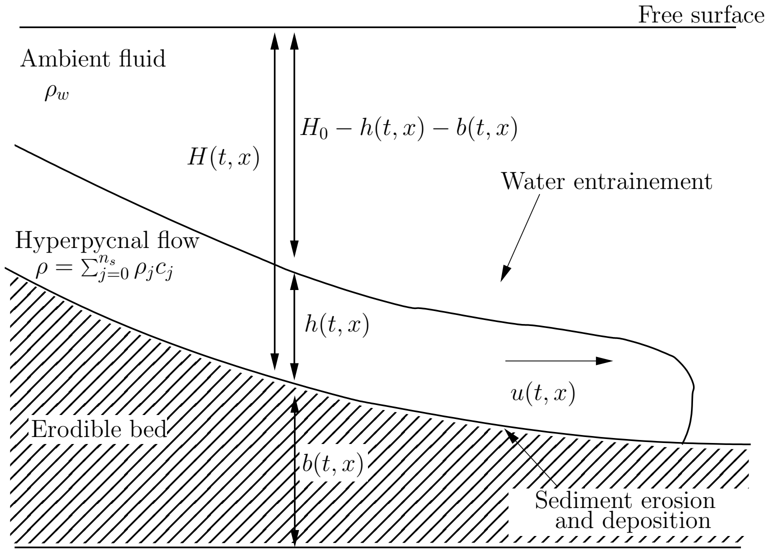

Figure 1: Sketch of hyperpycnal flow.

There is great interest in turbidity currents because of their profound impact on the morphology of the continental shelves and ocean basins of the world. It is commonly accepted that they are one of the potential processes through which sediments can be transferred to the deep sea environments. These bottom currents influence the sea bed morphology by depositing, eroding and dispersing large quantities of sediment particles. The resultant deposit often form porous layer of rocks which are potential sources of hydrocarbon. Therefore, understanding and predicting the geometry of these deposits is crucial for effectively exploring and exploiting these reservoirs.

An additional concern is the destructive effect that turbidity currents have on underwater structures, such as cables, pipelines and foundations.

Large-scale hyperpycnal flow or turbidity currents in the natural environment are difficult to monitor because of the unpredictable nature of the events. As a result, most of our knowledge about these flows is derived from small scale laboratory experiments like the ones described in [1,12,17,18,20].

Some layer-averaged models have been previously developed on the basis of small-scale tank experiments of particle-driven density currents in [6,9,16–18,24]. The partial differential equation (PDE) system of these models share a common structure, but different parametrization of the relevant mechanisms (deposition, erosion, water entrainment, etc.).

The first goal of this article is to improve this PDE system of the averaged models in order to include some missing effects that we consider to be relevant. More precisely:

1. in the absence of water entrainment, the freshwater mass in the turbidity current should be preserved;