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Large Eddy Simulations of Compositional Density Currents Flowing Over a Mobile Bed

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Density currents are a ubiquitous phenomenon caused by natural events or anthropogenic activities, and play an important role in the global sediment cycle; they are agents of long distance sediment transport in lakes, seas and oceans. Density gradients induced by salinity, temperature differences, or by the presence of suspended material are all possible triggers of a current. Such flows can travel long distances while eroding or depositing bed materials. This can provoke rapid topological changes, which makes the estimation of their transport capacity of prime interest for environmental engineering. Despite their relevance, field data regarding their dynamics is limited due to density currents scattered and unpredictable occurrence in nature. For this reason, laboratory experiments and numerical simulations have been a preferred way to investigate sediment transport processes associated to density currents. The study of entrainment and deposition processes requires detailed data of velocities spatial and temporal distributions in the boundary layer and bed shear stress, which are troublesome to obtain in laboratory. Motivated by this, we present 3D wall-resolved Large Eddy Simulations (LES) of density currents generated by lock-exchange. The currents travel over a smooth flat bed, which includes a section composed by erodible fine sediment susceptible of eroding. Several sediment sizes and initial density gradients are considered. The grid is set to resolve the velocity field within the boundary layer of the current (a tiny fraction of the total height), which in turn allows to obtain predictions of the bed shear stress. The numerical outcomes are compared with experimental data obtained with an analogous laboratory setting. In laboratory experiments salinity was chosen for generating the initial density gradient in order to facilitate the identification of entrained particles, since salt does not hinder the possibility to track suspended particles. Under these circumstances, it is possible to focus alone on the effect of the dynamics of the current on the particles entrainment. To achieve this, LES-filtered Navier-Stokes equations are coupled with two scalar transport equations: one for salinity and one for sediment concentration. We discuss the use of different sediment pick-up and settling formulations, which are key factors in reproducing the correct erosion and sedimentation mechanisms. The simulations show the emergence of longitudinal bed forms, and highlight the role of turbulent structures in the entrainment pattern for different regions within the current.