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Laboratorial study of continuously fed low-submergence gravity currents over smooth and rough beds

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Density or gravity currents are geophysical flows driven by density differences between two fluids which may be caused by temperature differences, dissolved substances or particles in suspension, among others. Examples of gravity currents include: in the atmosphere, sea breeze fronts driven by differences in temperature, avalanches of airborne snow, plumes of pyroclasts from volcanic eruptions and sand storms driven by suspended particles; in the water, oceanic fronts, resulting from differences in temperature and salinity, and turbidity currents caused by suspended particles. The release of pollutants into rivers and oceans and desalination plant outflows are examples of anthropogenic gravity currents frequently with negative environmental impacts. Closures for governing equations of gravity currents, mass and momentum conservation equations, are needed in what concerns the interaction between these and the lower fixed-bed and the upper permeable boundary. Herein experimental data obtained under laboratory controlled conditions is used to investigate the interaction between density currents and the fixed bed and the surrounding fluid. Instantaneous velocities are analyzed and discussed after application of double-averaging methods (D-AM), in time and space, for data processing. Experiments were performed at the Laboratory of Hydraulics and Water Resources, Department of Civil Engineering and Architecture at Instituto Superior Técnico, in a 12.5 m long, 40.9 cm wide and 50 cm deep recirculating, glass-walled channel with variable slope. Saline currents with two different initial densities of 1010 and 1020 kg/m^3 were simulated over two types of horizontal beds (smooth and rough constituted by one layer of cobbles with 3.5 mm mean diameter) into the channel filled with fresh water (density of approximately 1000 kg/m^3). The saline water was injected continuously, by means of a submersible pump (flow rate of 0.0339 l/s), at the upstream section of the channel and let flow through the lower layer of the channel. The water depth in the channel was between 11 and 13.8 cm and a downstream controlled outlet allowed keeping the water level constant during the experiments. Measurement of the instantaneous velocity fields of the flow were made with PIV instrumentation. This allows the photographic record of the position of tracing particles (both added in the saline solution and water at room temperature) within the measurement zone illuminated by means of a laser sheet, using a CCD camera. Two-dimensional instantaneous velocities are inferred, based on the determination of the displacement of the tracer particles in the time interval between two flow images acquired consecutively, by application of an adaptive-correlation algorithm. A return flow is observed with velocities of the same order of magnitude of the main density current. The application of D-AM to the velocity measurements allows the interpretation of turbulent mechanisms at the interface between the bed and the current and between the surrounding fluid and the current by analysis of velocity profiles, Reynolds stresses and dispersive stresses. The latter ensue from the intermittency in time and space of both lower and upper boundaries of the current.

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