Geophysical Research Abstracts
Vol. 14, EGU2012-3486, 2012
EGU General Assembly 2012

Periodic cycle of stretching and breaking of the head of gravity currents

H.I.S. Nogueira (1), C. Adduce (2), E. Alves (3), and M.J. Franca (4)

(1) Department of Civil Engineering & IMAR CMA, University of Coimbra, Portugal, (2) Department of Civil Engineering University of Rome, “Roma Tre”, Italy, (3) Department of Hydraulics and Environment National Laboratory of Civil Engineering, Lisbon, Portugal, (4) Department of Civil Engineering & IMAR CMA New University of Lisbon, Portugal

Gravity currents, which are geophysical flows driven by density differences within a fluid, are herein investigated under unsteady conditions by means of lock-exchange releases of saline water into a fresh water tank. Generally, gravity or density currents are caused by temperature differences or the presence of dissolved substances or particles in suspension. Examples of gravity currents include avalanches of airborne snow and plumes of pyroclasts from volcanic eruptions, in the atmosphere, releases of pollutants and turbidity currents, in rivers, lakes and reservoirs, and oil spillage and oceanic fronts in the ocean. A controlled and convenient fashion to investigate in detail hydrodynamics of unsteady gravity currents is by means of lock-exchange experiments.

The propagation of unsteady density currents, produced by lock exchange experiments, present three distinct phases, a first so-called slumping phase when buoyancy and inertial effects are balanced and front celerity is constant, a second (self-similar) phase when the reflected bore from the upper layer ambient fluid upstream drive, caused by continuity within the limited length tank, reaches the current front and causes the front celerity to decrease and provokes a diminution of the current head and, finally, a third viscous phase when viscosity plays a role and its effects overcome inertial effects. On the first and second phase, the current propagation is ruled by buoyancy effects counterbalanced by inertia, Reynolds stresses on the upper mixing layer and bed shear. Buoyancy is reduced due to entrainment and consequently the front velocity, leading to lower Reynolds number flows allowing thus viscosity effects to play a role. As for its anatomy, the current presents two distinct regions, the head and the remaining body or tail. On the very first instants of the release, the flow is bulky driven by the whole current mass while the head is not yet well defined. Later, this detaches from the main body and its particular buoyancy drives the advance of the current, with a different celerity from the tail. The head is highly concentrated being the main engine of convection of the released mass, being subjected to entrainment at the interface with the ambient fluid. The aim of the present work is to experimentally investigate the dynamics of the head, including continuous entrainment and cycles of stretching and breaking observed in the laboratory.

Experiments were conducted at the Laboratory of Hydraulics of University of Rome “Roma Tre” in a 3.0 m long, 0.20 m wide and 0.30 m deep transparent Perspex flume. Four lock-exchange release tests were performed varying the density of the saline water. For smooth bed and for a fixed value of water depth, h = 0.20 m, the following four different initial densities of the salt-water mixture were analysed: 1015, 1030, 1045 and 1060 kg/m3. A controlled quantity of dye is added to the saline water in the lock to provide flow visualization and to serve as density tracer. The development of the current is recorded with a 25 Hz CCD camera under controlled light conditions. The resulting video frames are thus converted into grey scale matrices and a calibration procedure establishes a non-linear relation, experimentally determined, between the gray scale values and the quantity of dye in the water. The quantity of dye is converted into salt concentration by assuming a linear relation between quantities, dye and salt, allowing thus the estimation of the 2D instantaneous current density distribution.

The experiments allowed the observation of the dynamics of the head of unsteady density currents in detail, including a cyclic increase in dimension and mass due to entrainment followed by a division in two distinct patches. A frontal one continues the drive downstream whereas a subsequent one is left behind and incorporated in the tail, thus indicating that the loss of saline mass in the head is not only due to continuous entrainment at the interface layer. Entrainment follows a decaying trend along the current development whereas periodic division of the head seems to be kept. The division of the head is related to mass ejections directing upstream with a clear signature in the current-depth time and spatial evolution maps. Initial density of the released saline current seems to be related to the period of the cyclic division of the head and the amplitude of the mentioned mass ejections; averaged periods of the occurrence of the divisions are 3.40, 1.63, 1.07 and 0.91 s respectively for initial densities of the salt-water mixture corresponding to 1015, 1030, 1045 and 1060 kg/m3.

Research supported by Portuguese Foundation for Science and Technology through the research project

PTDC/ECM/099752/2008 and the PhD grant SFRH/BD/48705/2008.