An experimental study of flow regimes of a gravity current over a Cape in a stratified environment

Javad Babagoli Matikolaei & Abbasali Aliakbari Bidokhti

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Abstract
Properties of the flow generated by a buoyancy source are investigated by a number of laboratory experiments. Experiments are carried out in a tank with a Cape to simulate the features of a gravity current when moving and separating over a delta Cape as in a real marine flow. Of the many experiments performed, 63 are recorded and analyzed in detail. Most of the experiments are carried out under $0.01 < Fr < 3$ and $0.03 < Ro < 0.45$ (where $Fr$ and $Ro$ are the Froude and Rossby numbers respectively). Dimensionless parameters of the simulations of the flow in a laboratory are comparable with those of the real flow in the Caspian Sea. Based on the behavior of flow upstream of the Cape, three regimes can occur in these experiments: laminar, eddy, and laminar-eddy regimes. The eddy regime is found for values of the Rossby number less than 0.05. For the moving flow on the bottom slope, an empirical relation between $C_{Nop}$, the Nof speed, and $u$, the current speed, is found from which $C_{Nop}$ is predicted from $u$ using oceanographic data. Based on the Rossby number of the flow in the Caspian Sea, the laminar-eddy regime is more likely to occur. The flow shows a different behavior when moving over the Cape which is categorized by the Cape upstream behavior of the flow. Under $g = 0.02 \text{ m s}^{-2}, f = 0.72 \text{ s}^{-1} (T = 17 \text{ s}), Ro = 0.17$, and $Fr = 0.24$, one cyclone eddy and one anticyclone eddy are formed similar to those seen in nature (here the Caspian Sea). In the eddy regime, the cascade process occurs with a timescale of longevity $t_i < 67$ for each eddy. The results indicate that the geometry of the Cape and the features of the flow ($g, Fr$, and $Ro$) upstream can be effective in the shape, size, and location of eddy formation. The experimental results also show that the radius of the eddy is about two times larger than the Rossby deformation radius of the flow in upstream of the Cape, while having a timescale $t_i$ between $T/2$ and $2T$. In nature, the eddy formation and development time scale are about 1 to 2 years with 10 and 15 months for Seddy (cyclone eddy) and Aeddy (anticyclone eddy) respectively. Because of the ability of an eddy to transport and spread pollutants such as oil in the southern Caspian Sea, this work can also be important for the marine dispersion estimations.

Keywords Density driven flow - Rotating fluid - Eddy shedding - Sediment Delta Cape - Cyclonic and anticyclonic eddies

1 Introduction
The density (gravity) currents play a pivotal role in ocean circulation and earth climate. These currents appear as outflow or overflow over the sill of straits while descending from the continental shelves into the deep ocean. The DSO (Denmark Strait Overflow) is one of the most important dense flow because of it being an important component of the thermohaline ocean circulation while carrying approximately half of the dense water formed in high latitudes, into the Greenland, Iceland, and Norwegian seas (Girton and Sanford 2003). In smaller scales, the Mediterranean density current outflows into the Atlantic Ocean, through the Strait of Gibraltar, because of the density differences between the waters of the two basins (Garcia-Lafruit et al. 2017). Density variations in the ocean are directly associated with the temperature and also salinity variations in the global oceans (Price and Baringer 1994). For understanding the structure of such density current, there are a number of methods used by researchers in the last 40 years. In order to avoid complications from that of nature and control of any relevant current physical parameters, several works used laboratory experiments to...