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ABSTRACT

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Doctor of Philosophy

ROTATING EXCHANGE FLOWS THROUGH STRAITS WITH MULTIPLE CHANNELS

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Ocean basins are connected by straits and passages geometrically limiting important heat and salt exchanges which in turn influence the global thermohaline circulation and climate. Such exchange can be modelled in an idealised way by taking into consideration the density-driven two-layer flow along the strait and the influence of rotation, in particular when the first mode baroclinic Rossby radius is of the same order or smaller than strait width. Some straits have complex bottom topography, such as the Strait of Sicily or the Straits of Hormuz. It is is the objective of this study to understand when and why this has to be taken into consideration.

We use a laboratory model of a lock exchange between two reservoirs of different density through a flat-bottom channel with a horizontal narrows, set up on two different platforms: a 1m diameter turntable, where density interface position was measured by dye attenuation, and the 14m diameter turntable at Coriolis/LEGI (Grenoble, France). On the latter, this type of experiment was carried out for the first time, measuring velocity using Correlation Imaging Velocimetry, a particle imaging technique. In all experiments, the influence of rotation is studied by varying a parameter, R_0, the ratio of the Rossby radius to the channel width at the narrows. In addition, the simple channel is modified by adding a central island to represent straits with non-uniform topography at the narrows.

Results show that the quasi-steady exchange flux for simple channels varies in a way similar to a theoretical prediction by Whitehead *et al.* (1974). When an island is introduced, the dimensional flux is larger than without an island for $R_0 \sim 1$. However, the total exchange is less than the sum of exchanges that would be expected from each individual channel. Furthermore, for $R_0 > 1$ the non-dimensional cross-channel slope at the narrows is shallower than predicted by Dalziel (1988)'s semi-geostrophic theory for simple channels. However, scaling R_0 using a reduced channel width in the island cases leads to a variation of these quantities with R_0 in accordance with theory. For $R_0 > 1$ two-layer flow persisted across the channel at the narrows with or without an island, but distinctly different flows occurred for lower R_0. One quasi-steady state with $R_0 \sim 0.7$ showed a 'split' regime with upper and lower layer currents passing on different sides of the island (left, looking downstream, respectively). A recirculation near the island tips was noticeable, particularly for $R_0 << 1$, where distinct jets circulated around the tips, opposing the flow of same density on the other side of the island. A similar phenomenon has been found in some oceanic strait flows. Flow at very low R_0 did not appear to reach a steady state but instead showed an oscillating current around the narrows associated with several, often barotropic, vortices. Instantaneous flow fields in those cases, however, still showed an exchange between the reservoirs, with one island case showing a flow split by the island and almost barotropic on either side. There, fluxes were twice as high as predicted by two-layer theory.

Our study showed that the combination of rotation and an island introduce significant 3-dimensional aspects to the flow, not present in non-rotating exchange flows.