SHORTER CONTRIBUTION

A note on eastern boundary currents in a laboratory analogue of the ocean circulation[1]

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In a paper published in Tellus several years ago (Faller, 1960) it was pointed out that under certain experimental conditions flow injected through a slot in the eastern boundary of a rotating bounded basin resulted in an unexpected eastern boundary current. It was postulated at the time that the observed flow was related to the negative absolute vorticity in a small fraction of the flow that emerged through the narrow slot in the eastern boundary, and it was suggested that the fraction of flow that moved along the eastern boundary might be related to the fraction of flow that emerged from the slot with negative absolute vorticity. We have repeated some of the experiments and it is now believed that the observed current resulted from small density differences.

Fig. 1 illustrates the overall geometry of the problem and Fig. 2 shows details of the source channel through the eastern boundary. The length of the channel was sufficiently long and the width W was narrow enough to assure a good approximation to plane Poiseuille flow. The fraction of flow with negative absolute vorticity, $\zeta_a = \zeta + 2\Omega < 0$, where ζ is the vertical component of the relative vorticity and Ω is the angular rotation speed of the system, is easily calculated to be

$$\frac{S^*}{S} = \frac{1}{2}\left(1 - \frac{H\Omega W^2}{2S} + \frac{1}{9}\left(\frac{H\Omega W^2}{2S}\right)^3\right)$$

where S is the total flow rate, S^* is the flow rate of fluid with $\zeta_a < 0$, and H is the fluid depth. In the earlier experiments the specific values were $\Omega = 1.05\ \mathrm{s}^{-1}$, $H = 8$ cm, $W = 0.825$ cm, and $S = 1.833\ \mathrm{cm}^3\,\mathrm{s}^{-1}$. The resulting ratio was $S^*/S = 0.082$, in good agreement with the observed flow of approximately $S_2/S = 0.10$ moving along the eastern boundary.

Our recent experiments with the same basic apparatus were designed to compare the observed fraction S_2/S with the fraction of flow S^*/S. After only a few experiments it became clear that with careful control of the temperature of the inflow there is no eastern boundary current to be found. In one experiment with adequate flow but with no eastern boundary

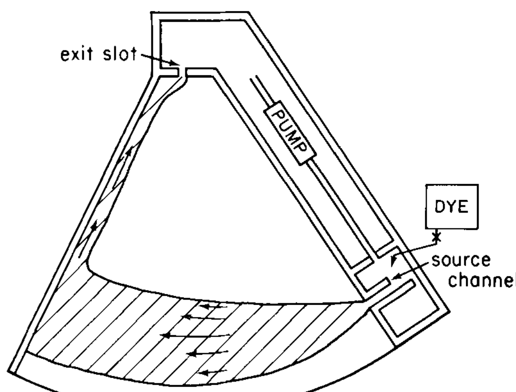

Fig. 1. The basic geometry of the bounded basin, a 60° sector of 100 cm radius, placed upon a rotating turntable with the rotation axis at the apex of the sector. The supply of input water and the sector were covered with glass and sealed to eliminate heat loss by evaporation.

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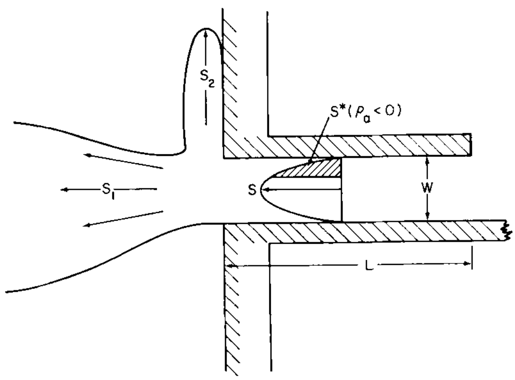

Fig. 2. Details of the entrance slot and designation of the flow components.

current we altered the density of the inflow simply by adding an ice cube to the water supply. An eastern boundary current, typical of the earlier experimental results, quickly developed. Therefore we believe that the earlier findings were a result of inadequate control of the temperature of the source water. In both sets of experiments the concentration of dye (methyene blue) was at a level for which the change in specific gravity of the solution was small compared to possible thermal effects.

At some of the higher flow speeds a series of eddies were generated at the edges of the channel, and in some cases remnants of these might have been interpreted as a weak boundary current. To check the possible influence of the sharp corners of the entrance slot, we rounded the corners to a radius of 3 mm. This served only to smooth the entering flow and no eddies or boundary currents appeared.

Although in these experiments we have not systematically covered the various non-dimensional parameters of the problem, we conclude that earlier experiments had insufficient thermal control and that the observed eastern boundary currents were due to differences in the specific gravity of the source water and the interior water. Nevertheless, boundary currents due to gradients of the specific gravity, perhaps with viscous effects, do indeed occur, and the proposed analogy of the original experimental results with flow from the Straights of Gibraltar along the coast of Portugal may have some validity. Detailed study of density-driven boundary currents remains for further experimental and theoretical study.

REFERENCES

Faller, A. J. 1960. Further examples of stationary planetary flow patterns in bounded basins. *Tellus* *12*, 159–171.