The anatomy of a draining vortex in a rotating bathtub

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Abstract

A remarkable feature of the vortex driven by a sink in the bottom of a rotating fluid container is the pronounced upward motion around the fast-rotating cyclonic vortex core with downward motion into the sink. This phenomenon is clearly observed by dye visualisation of the flow near the sink: the flow towards the sink is confined to the Ekman layer at the tank bottom, in which it spirals inwards. Before reaching the sink the fluid first rises to a substantial height, and subsequently flows downwards to the sink in the core of the vortex.

Although this phenomenon has been observed before[1,2], a full explanation was still lacking. We have performed a theoretical analysis of the flow near and in the draining vortex, by distinguishing different dynamical balances at different distances from the sink: a geostrophic potential flow at large distance, and a gradient flow and a cyclostrophic flow balance, respectively, when moving closer to the sink. The theoretical prediction of the flow behaviour in the sink vortex agrees well with the experimental observations.

Additional numerical simulations show very good agreement with the theoretical model.

References

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