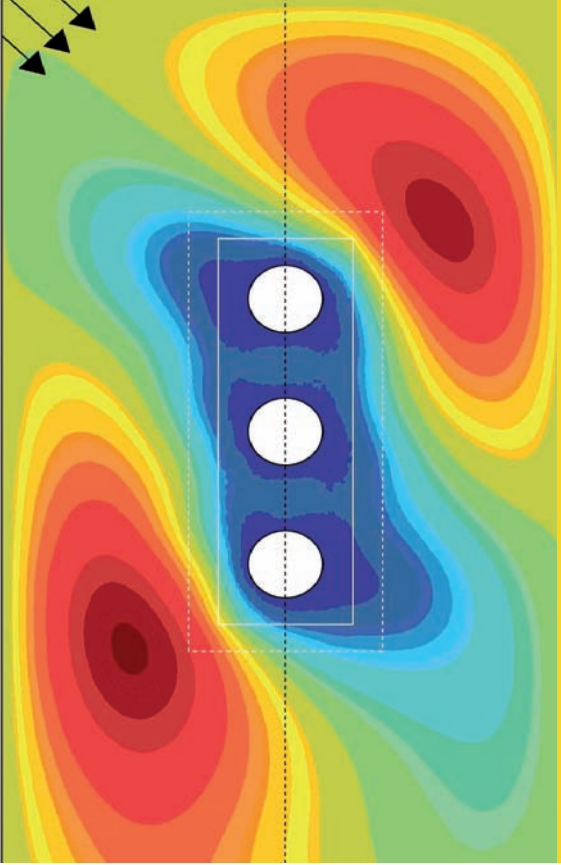
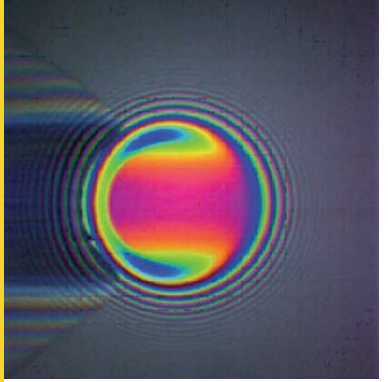
On 3D structures of dipolar vortices in a shallow fluid layer





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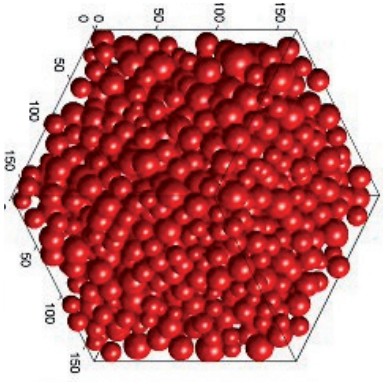

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J.M. Burgerscentrum
Research School for Fluid Mechanics
TUD, TUE, UT, RUG, RUN, UL, WUR

TU/e technische universiteit eindhoven

On 3D structures of dipolar vortices in a shallow fluid layer

R.A.D. Akkermans, A.R. Cieslik, L.P.J. Kamp, H.J.H. Clercx and G.J.F. van Heijst

Introduction

"Do flows in a shallow fluid behave quasi-2D?"

Experimental setup

The experiments have been performed in a shallow layer of electrolyte, in which the dipolar motion is generated by electromagnetic forcing (see Fig. 1).

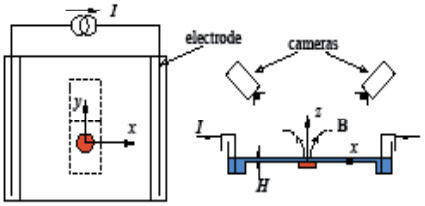

Fig. 1: Schematic drawing of the setup. Left: top view, right: cross-section.

Tools used for investigation:

- ★ Stereoscopic PIV.
- ★ 3D numerical simulations.

Results

Significant vertical motions are present both during the forcing and after the forcing of the flow has been switched off.

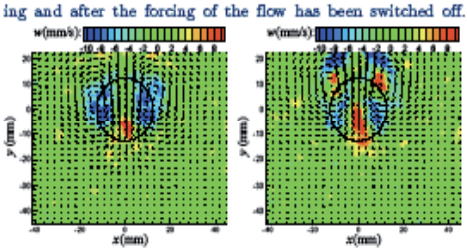

Fig. 2: Vertical velocity fields at the end of the forcing (left) and after forcing (right).

Quasi-2D behaviour of the flow in the shallow fluid seems to be destroyed. The origin of these strong residual flows is the topic of this investigation.

Among the features seen during the forcing period:

- ★ Two well-defined regions of vertical (downward) motion are present inside the vortices.
- ★ Strong upward motion at the tail of the dipole.

The flow field during forcing (Fig.2) and after forcing (Fig.3) is essentially different, the 3D motion remains significant long after the forcing has stopped.

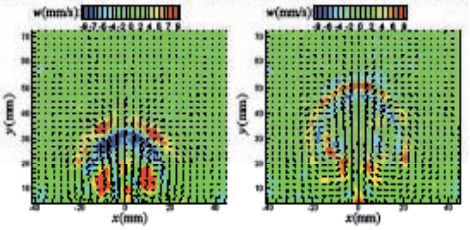

Fig. 3: Experimentally obtained velocity fields after forcing.

Among these 3D structures are:

- ★ In front of the dipole we see a roll-like structure: "the frontal circulation".
- ★ Inside the vortex cores upward motion is seen, in contrast to downward motion during forcing.
- ★ Oscillating vertical fluid motion is seen inside the individual vortex cores.

To illustrate the 3D structure inside the vortices, numerical velocity distributions in a vertical slice are displayed:

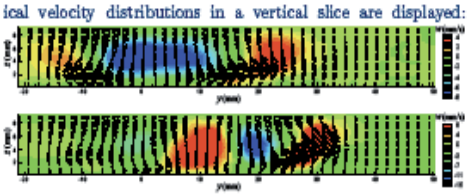

Fig. 4: Numerically obtained velocity fields at end stage (top) of forcing and after forcing (bottom). (colors: vertical velocity w).

- ★ The vertical structure is **not** quasi-2D flow, i.e. not a planar flow with a Poiseuille-like vertical structure.
- ★ Additional simulations show that confinement is important in generating vertical motion, not bottom friction, (free) surface deformation or electromagnetic forcing.

Acknowledgements

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/department of applied physics /fluid dynamics laboratory