Figure 1: Sketch of the experimental set-up

INFLUENCE OF THE MAGNETIC FIELD ON A LIQUID GALLIUM VORTEX

Daniel BRITO, Philippe CARDIN, and Henri-Claude NATAF
Département Terre Atmosphère Océan, École Normale Supérieure,
24 rue Lhomond, 75231 Paris 05, France

Convection in the Earth's core is controlled by the Coriolis and Lorentz forces. Yet, little is known of the flow patterns that form under their influence. In the absence of a magnetic field, convection organizes itself in long mobile vortices with their axes parallel to the rotation axis. In order to gain some insight on the behaviour of the flow in the presence of a magnetic field, we have set up the following laboratory experiment :

A single vertical vortex is created in an 8 cm-diameter cylinder by spining a 4 cm-diameter disk at its base at rotation rates up to 700 rpm. The 22 cm-high cylinder is filled with liquid gallium, a metallic liquid. The cylinder is placed between the 14 cm-diameter poles of a magnet,which produces a horizontal magnetic field whose intensity can reach 0.1 T. Figure 1 depicts the experimental set-up. We use 3 methods to deduce the velocity field.

- We measure the pressure (for a rigid top) or the deformation (for a free surface) at the top of the cylinder.
- We put some electrodes A,B,C,D along the height of the cylinder and measure electrical potentials at these points.
- With a gaussmeter, we measure the magnetic field advected by the flow.

In this experiment, we can obtain Magnetic Reynolds number $Re_m \leq 0.3$ and Ekmann number $E \geq 10^{-4}$.

The first effect of the magnetic field is to severely decrease the rotation of the liquid. Figure 2 shows two profiles of the free surface deflection with and without a magnetic field. The profiles are well explained with a model in which rigid rotation in the central part of the vortex is matched with simple shear to the wall of the cylinder (dashed line). The modeling enables us to detect the second effect of the magnetic field, which is to increase the radius of the vortex.

Strong Foucault electrical currents are generated in the cylinder. They consist in a loop of current in the vertical plane that contains the B vector, with upwards current on the left and downwards current on the right, in Figure 1. We model this electrical currents by solving Poisson's equation in a vertical plane, using the velocity field derived previously. The predicted electrical potentials are in a good agreement with the measured ones.

The magnetic field induced by the flow in the cylinder is illustrated in Figure 3. This is the representation of the magnetic field in the median horizontal plane of the cylinder.

Figure 2: Topograpy of the free surface.

The magnetic field induced by the vortex has the geometry of a dipole orthogonal to the axis rotation of the spining disk and orthogonal to the imposed magnetic field. It is mainly created by a big loop of current described above. We measure the induced magnetic field outside the cylinder.

The experiment is now conducted on a rotating table so as to investigate the effect of the Coriolis force. The rotating table spins at speed up to 50 rpm. We obtain Elsasser number $\Lambda \leq 10$. Preliminary results of this experiment will be presented.

Figure 3: Induced magnetic field in the median horizontal plane.The imposed magnetic field is orientated from left to rigth. and the vortex rotates clockwise.