Vertical velocities in quasi-geostrophic floating vortices

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Oceanic structures subjected to the Earth's rotation are driven by geostrophic equilibrium which allows large-scale oceanographic models to successfully reproduce the near-two-dimensional dynamics of large eddies and currents. However, fine-scale ocean structures, such as vortices, fronts, filaments, waves emerge and escape this description. They generate three-dimensional movements which therefore break the geostrophic equilibrium. Measurements and understanding of these fine-scale vertical motions are one of the main open questions among the oceanography community, as they are most likely responsible for ocean mixing and have a strong impact on the transport of biologic and chemical components as well as on the climate evolution.

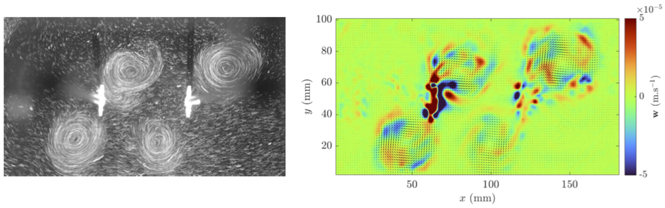

Figure 1. (a) Superimposition of raw images of four floating vortices. (b) Resulting **w** (m/s) field obtained from the ω-equation model (Eq. (1)).

We focus here on three-dimensional motions in floating vortices resulting from the balance between the Coriolis force and the density gradients [1]. If the most intense velocities are horizontal as we would expect from geostrophy, their shape is connected to small vertical velocities. Therefore, the aim of this study is to measure experimentally these vertical motions. This is especially challenging because vertical velocities are smaller by several orders of magnitudes compared to the horizontal velocities. The floating vortices will be produced by injecting dyed pure water at the surface of a salt water rotating volume (Fig. 1). PIV and particle tracking are the method of choice to measure horizontal and vertical velocity fields and LIF is used to measure density fields. The results are then compared to predictions from oceanographers model given by the ω-equation [2] :

$$N^2 \nabla_h^2 \mathbf{w} + f^2 \frac{\partial^2 \mathbf{w}}{\partial z^2} = 2\nabla_h \cdot (\nabla_h \mathbf{u_g} \cdot \nabla_h \rho) \tag{1}$$

with $\mathbf{w}$ the ageostrophic vertical velocity, $\mathbf{u_g}$ the geostrophic horizontal velocity field, ρ the density, f the Coriolis frequency, N the Brunt–Väisälä frequency and ∇_h the horizontal gradients.

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References

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