Wave field and zonal flow of a librating disk

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Abstract

In this work, we provide an exact viscous solution of the wave field generated by librating a disk (harmonic oscillation of the rotation rate) in a stably stratified rotating fluid. The zonal flow (meanflow correction) generated by the nonlinear interaction of the wave field is also calculated in the weakly nonlinear framework. We focus on the low dissipative limit relevant for geophysical applications and for which the wave field and the zonal flow exhibit generic features. General expressions are obtained which depend on the disk radius a, the libration frequency ω, the rotation rate Ω of the frame, the buoyancy frequency N of the fluid, its kinematic diffusion ν and its thermal diffusivity κ. When the libration frequency is in the inertia-gravity frequency interval ($\min(\Omega, N) < \omega < \max(\Omega, N)$), the presence of conical internal shear layers is observed in which the spatial structures of the harmonic response and of the meanflow correction are provided. At the point of focus of these internal shear layers on the rotation axis, the largest amplitudes are obtained: the angular velocity of the harmonic response and the meanflow correction are found to be $O(\varepsilon E^{-1/3})$ and $(\varepsilon^2 E^{-2/3})$ respectively where ε is the libration amplitude and $E = \nu/(\Omega a^2)$ is the Ekman number.

We show that the solution in the internal shear layers and in the focus region is at leading order the same as that generated by a Dirac oscillating ring source of axial flow placed at the edge of the disk.