Evolution of secondary whirls in thermoconvective vertical vortices in a route to chaos

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The appearance, evolution and disappearance of periodic and quasiperiodic dynamics of fluid flows in a cylindrical annulus locally heated from below are analysed using nonlinear simulations. The results reveal a route of the transition from a steady axisymmetric vertical vortex to a chaotic flow. The chaotic flow regime is reached after a sequence of successive supercritical Hopf bifurcations to periodic, quasiperiodic and chaotic flow regimes. A scenario similar to the Ruelle-Takens-Newhouse scenario [3] is verified in this convective flow. In the transition to chaos we find the appearance of subvortices embedded in the primary axisymmetric vortex, flows where the subvortical structure strengthens and weakens, almost disappears before reforming again, leading to a more disorganized flow to a final chaotic regime. Results are remarkable as they connect to observations describing the formation, weakening and virtually disappearence before revival of subvortices in some atmospheric swirls such as dust devils [4]. The numerical results have been obtained by direct simulation of the time-dependent governing equations, incompressible Navier-Stokes coupled with a heat equation under Boussinesq approximation. These equations have been solved using the second-order time-splitting method. A pseudo-spectral method is used for the spatial discretization, with a Fourier expansion in the azimuthal coordinate and Chebyshev collocation in the radial and vertical coordinates. These works have been published in [1, 2].

Keywords: natural convection, espectral methods, vertical vortex.

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