Nonlinear dynamics of coherent and chaotic vortex perturbations in physical and Fourier space

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Abstract This work examines the nonlinear dynamics of coherent and chaotic perturbations in two-dimensional hydrodynamic shear flows [1]. The interaction of linear and nonlinear processes during self-organizing processes is studied, with a focus on the role of nonlinearity in the self-sustainability of coherent and chaotic vortices. Initially, the classical theory of the turbulence spectrum is presented, following Kolmogorov's approach [2], which is strictly valid for isotropic turbulence in the inertial range of Fourier/spectral space. Subsequently, the spectral energy equation for perturbations is derived from the two-dimensional, incompressible, viscous fluid equations, taking into account the presence of shear flow, with each term in the equation analyzed. The equations are numerically solved for three types of perturbations: cyclonic, anticyclonic, and stochastic. For each type of perturbation, the energy, nonlinear term, Reynolds stresses, and other linear processes in the spectral plane at any given moment are constructed from the obtained solutions. The dynamics of each of these terms are analyzed. It is shown that nonlinearity induces a transverse cascade of spectral energy. For anticyclonic perturbations, the total energy monotonically increases during numerical calculations, due to positive nonlinear feedback. For cyclonic and chaotic perturbations, the total energy oscillates, caused by the alternating sign of the nonlinear feedback term. When the total energy increases, the feedback is positive; when it decreases, the feedback is negative. To understand these phenomena, the intensities of radial and transverse cascades are numerically calculated in circular rings of various wave number ranges in Fourier space.

References:

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