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Hydrodynamic instability of vertical motions initiated by spatially periodic heat sources in the atmosphere

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The problem of the hydrodynamic stability of a system of vertical flows (updrafts and downdrafts) initiated by spatially periodic heat (buoyancy) sources is investigated. Such sources serve as a rough model of latent heat sources in the atmosphere, and the flows themselves model the organized system of convective clouds observed over the oceans. To describe the dynamics of perturbations, the Galerkin method was used. The dynamic equations are reduced to a system of three equations for the coefficients of the expansion of perturbations in a trigonometric Fourier series. Within this framework, a linear theory of the stability of a system of vertical flows in a stably stratified atmosphere is developed. It is shown that in the absence of dissipative factors, this flow system is unstable if the analogue of the Richardson number is less than one-eighth. An unexpected result was obtained when accounting for small-scale turbulent viscosity and thermal conductivity of the atmosphere. It was found that allowance for these dissipative factors leads to the appearance of an additional unstable mode. This mode existence greatly expands the region of instability in the plane of the determining parameters (Richardson and Reynolds numbers). When taking into account the Newtonian radiative cooling, the instability exists for all values of the determining parameters.

Along with the linear theory, an approach describing the nonlinear dynamics of perturbations of a system of vertical flows has been developed. It is based on the reduction of the Galerkin equations to a closed system of five ordinary differential equations (a pentad of equations). Within this framework, a weakly nonlinear theory of inviscid instability is developed. The results of preliminary numerical integrations of a pentad of equations with viscosity, thermal conductivity and Newtonian radiative cooling demonstrate various scenarios for the development of instability, including the transition from regular periodic in time behavior to chaotic dynamics.

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