Geophysical Research Abstracts
Vol. 13, EGU2011-10846, 2011
EGU General Assembly 2011

Exact Theory of 3D Infinitesimal Periodic Internal Gravity Wave Generation by Compact Sources: Extension of Classical Stokes Solution and Laboratory Experiment

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We analyzed solutions of the fundamental equations set for generation of 3D periodic flows by an oscillating piston in a viscous continuously stratified fluid taking into account diffusivity effects. Boundary conditions are no-slip and no-flux in solid surfaces and attenuation of all perturbations at infinity. Complete solution of linearized problem is constructed by method of integral decomposition. Obtained expressions are analysed using theory of singular perturbations in approximation of small dissipation selected as parameter of expansion. Complete solutions contain regularly perturbed functions on dissipative factors describing periodic internal wave cones which have no analogues in Stokes solution for homogeneous fluid and rich family of singularly perturbed components (sidics). Two kinds of sidics are caused by the action of viscosity, while others are resulted due to diffusion effects. Edge singular solutions are pronounced in the far beam structure. Parametric analysis of both dissipative factors that are viscosity and diffusivity as well as stratification value and geometry of the problem (cases of arbitrary sloping, horizontal, vertical critical angles of the emitting surface placing) is performed. Continuous transfers of the problem solution from 3D to 2D and further up to 1D posing problems are investigated. The analyzed 3D problem is matched continuously with direct solution of appropriate 2D problem for oscillating sloping strip. In limiting case of oscillating infinite plane in limit of zero buoyancy frequency the solution is matched continuously with classical Stokes solution for oscillation plane. Parametric analysis reveals critical sizes of the source corresponding transformation of the wave beam structure from unimodal into bimodal and limiting width of the beam for small sources. Numerical visualization has demonstrated the complex structure of the internal wave beam covered by thin twinkled high gradient envelopes. Comparison of calculated wave beams with laboratory schlieren visualization shows their qualitatively and quantitatively compatibility. Discontinuities in the domain of the beam singular components convergence and vortices formation resulting from the nonlinear interactions of the flow components are visualized at large amplitudes of the source oscillations.