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The primary nonlinear dynamics of modal and nonmodal perturbations of monochromatic inertia-gravity waves

U. Achatz

Leibniz-Institut fuer Atmosphaerenphysik an der Universitaet Rostock, Kuehlungsborn, Germany (achatz@iap-kborn.de/fax: +49-38293-6850)

The interaction between inertia-gravity waves (IGWs), their leading normal modes (NMs) or singular vectors (SVs), and the resulting small-scale eddies is investigated by means of direct numerical simulations of a Boussinesq fluid characterizing the upper mesosphere. The focus is on the primary 2.5-dimensional dynamics, neglecting the effect of secondary instabilities. It is found that the structures with the strongest impact on the IGW and also the largest turbulence amplitudes are the NM (for a statically unstable IGW) or short-term SV (statically and dynamically stable IGW) propagating horizontally transversely with respect to the IGW, possibly in agreement with observations of airglow ripples in conjunction with statically unstable IGWs. In both cases these leading structures reduce the IGW amplitude well below the static and dynamic instability thresholds. The resulting turbulent dissipation rates are within the range of available estimates from rocket soundings, even for IGWs at amplitudes low enough precluding NM instabilities. SVs thus can help explaining turbulence occurring under conditions not amenable for the classic interpretation via static and dynamic instability. Due to an important role of the statically enhanced roll mechanism in the energy exchange between IGW and eddies the turbulent velocity fields are often conspicuously anisotropic. The spatial turbulence distribution is determined to a large degree by the elliptically polarized horizontal velocity field of the IGW.