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Peculiarities of Transient Nonlinear Acoustic-Gravity Wave Propagation From the Lower to the Upper Atmosphere

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Acoustic-gravity waves (AGWs) observing at high altitudes could be generated in the lower atmosphere and can propagate upwards. An algorithm for numerical three-dimensional simulation of nonlinear AGWs propagation from the Earth's surface to the thermosphere was recently developed. The algorithm uses finite-difference analogues of basic conservation laws. This approach allows selecting physically correct generalized wave solutions of the nonlinear equations. Horizontally moving sinusoidal structures of vertical velocity on the Earth's surface serve as AGW sources in the model. Numerical simulation was made in a region of the Earth atmosphere with dimensions up to several thousand kilometers horizontally and 500 km vertically. Vertical profiles of the mean temperature, density, molecular viscosity and thermal conductivity are taken from standard models of the atmosphere.

Simulations are made for different amplitudes, horizontal wavelengths and speeds of wave sources at the lower boundary of the model. It is shown that after "switch on" tropospheric source atmospheric waves very quickly (for several minutes) may propagate to high altitudes (up to 100 km). When AGW amplitudes increase with height, waves may break down in the middle and upper atmosphere. Instability and dissipation of wave energy may lead to formations of wave accelerations of the mean winds and to creations of wave-induced jet flows in the middle and upper atmosphere. Nonlinear interactions may lead to instabilities of the initial wave and to the creation of smaller-scale structures. These smaller inhomogeneities may increase temperature and wind gradients and enhance the wave energy dissipation.

Simulations with background wind and temperature profiles corresponding to different levels of solar activity show that AGWs characteristics in the middle and upper atmosphere may change with changes in solar activity. This may alter heating and acceleration of the different layers of the atmosphere and change conditions of dynamical coupling between the lower and upper atmosphere. Transient processes of AGW formation and disappearing after "switch on" and "switch off" of the surface wave sources are also considered. This work was partially supported by the Russian Basic Research Foundation (# 17-05-00458).