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Dissipation of atmospheric waves: An asymptotic approach

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Wave energy dissipation through irreversible thermodynamic processes is a major factor influencing propagation of acoustic and gravity waves in the Earth's atmosphere. Accurate modeling of the wave dissipation is important in a wide range of problems from understanding the momentum and energy transport by waves into the upper atmosphere to predicting long-range propagation of infrasound to the acoustic remote sensing of mesospheric and thermospheric winds. Variations with height of the mass density, kinematic viscosity, and other physical parameters of the atmosphere have a profound effect on the wave dissipation and its frequency dependence. To characterize the wave dissipation, it is typical to consider an idealized environment, which admits plane-wave solutions. For instance, kinematic viscosity is often assumed to be constant in derivations of dispersion equations of acoustic-gravity waves in the atmosphere. While the assumption of constant shear viscosity coefficient would be much more realistic, it does not lead to plane-wave solutions. Here, we use an asymptotic approach to derivation of dispersion equations of acoustic-gravity waves in dissipative fluids. The approach does not presuppose existence of any plane-wave solutions and relies instead on the assumption that spatial variations of environmental parameters are gradual. The atmosphere is modeled as a neutral, horizontally stratified, moving ideal gas of variable composition. Linearized hydrodynamic equations for compressible fluids in a gravity field are solved asymptotically, leading to a self-consistent version of the Wentzel-Kramers-Brillouin approximation for acoustic-gravity waves. Dissipative processes are found to affect both the eikonal and the geometric (Berry) phase of the wave. Newly found expressions for acoustic-gravity wave attenuation due to viscosity and thermal conductivity of the air are compared to results previously reported in the literature. Effects of the wind on the wave dissipation prove to be significant. Knowledge of the wind velocity profile is essential for accurate modeling of dissipation of the atmospheric waves.