Unification of the Anelastic and Quasi-Hydrostatic Systems

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A system of equations is presented that unifies the nonhydrostatic anelastic system and the quasi-hydrostatic elastic system for use in global cloud-resolving models. By using a properly defined quasi-hydrostatic density in the continuity equation, the system is elastic for quasi-hydrostatic motion and anelastic for purely nonhydrostatic motion. In this way, the system can govern the dynamics of a wide range of horizontal scales from turbulence to planetary waves while filtering vertically propagating sound waves of all scales. The continuity equation is primarily diagnostic because the time derivative of density is calculated from the thermodynamic (and surface pressure tendency) equations as a correction to the anelastic continuity equation. Neither reference state is used and nor approximations are made in the momentum and thermodynamic equations. An equation that governs the time change of total energy is also derived. Normal-mode analysis on an f plane without the quasigeostrophic approximation and on a midlatitude beta plane with the quasigeostrophic approximation is performed to compare the unified system with other systems.