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1 Unification of the anelastic and quasi-hydrostatic systems of equations

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A system of equations that unifies the anelastic and quasi-hydrostatic systems is presented for use in global cloud-resolving models. By using a properly defined quasi-hydrostatic density in the continuity equation, the system is fully compressible for quasi-hydrostatic motion and anelastic for purely nonhydrostatic motion. In this way, the system can cover a wide range of horizontal scales from turbulence to planetary waves while filtering vertically propagating sound waves of all scales. The continuity equation is still 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. No reference state is used and no approximations are made in the momentum and thermodynamic equations.

Normal-mode analysis using the middle-latitude beta-plane approximation is performed to compare the unified system with other systems. It is shown that both the pseudo-incompressible and unified systems remove the large systematic error of the anelastic system in the vertical structure. The unified system also reduces the westward retrogression speed of the barotropic Rossby wave through the inclusion of horizontal divergence due to compressibility.