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Comparisons of the Anelastic and Unified Modes Based on the Lorenz and Charney-Phillips Vertical Grids

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The anelastic and unified models based on the Lorenz and Charney-Phillips vertical grids are compared in view of nonhydrostatic simulation of buoyant bubbles. It is widely accepted that small-scale nonacoustic motions such as convection and turbulence are basically anelastic. The recently proposed unified system (Arakawa and Konor, 2009) unifies the anelastic and quasi-hydrostatic systems by including quasi-hydrostatic compressibility and, therefore, it can be used for simulating a wide range of motion from turbulence to planetary scales.

There are two basic grids for the vertical discretization of governing equations. The most commonly used vertical grid is the Lorenz grid (L-grid), on which the thermodynamic variables and the horizontal momentum are staggered from the vertical momentum. The other is the less commonly used Charney-Phillips grid (CP-grid), on which the thermodynamic variables and the vertical momentum are staggered from the horizontal momentum. The existence of a computational mode with the L-grid in the vertical structure of temperature is well-known. It should be also pointed out that, when the L-grid is used in a non-hydrostatic model, the buoyancy force cannot properly respond to the dynamically generated noise in the vertical velocity field. With the unified system of equations, however, we find that the dynamical generation of noise tends to be suppressed. This can be interpreted as a result of including the quasi-hydrostatic compressibility. Even when the motion is basically nonhydrostatic, the generated noise tends to be quasi-stationary and, therefore, quasi-hydrostatic. Although the original intention of including the quasi-hydrostatic compressibility in the unified system is to improve simulation of planetary waves, the results presented here indicate that the unified system can also better control small-scale computational noise without generating vertically propagating acoustic waves.

In this presentation, we show results from numerical simulations of buoyant bubbles by the anelastic and unified systems, and compare the continuous and discrete dispersion relations to interpret the simulation results.