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Design of a dynamical core based on the nonhydrostatic unified system of equations

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Design of a dry dynamical core based on the nonhydrostatic unified system of equations is presented, which filters the vertically propagating acoustic waves. The dynamical core can predict motion for a wide range of scales from the turbulence to planetary waves so that it can be used for a cloud-resolving global model. It predicts the potential temperature and horizontal momentum without any approximation. It uses the predicted potential temperature to determine the quasi-hydrostatic components of the Exner pressure and density. The continuity equation is diagnostic (and used to determine vertical mass flux) because the time derivative of the quasi-hydrostatic density is obtained from the predicted potential temperature. The nonhydrostatic component of the Exner pressure is obtained from an elliptic equation. The main focus of this paper is on the integration procedure of this unique dynamical core. In the dynamical core, a height vertical coordinate is used and the equations are vertically discretized on a Lorenz-type grid. The Cartesian horizontal coordinate is used along with an Arakawa C-grid for the horizontal discretization of the equations. A brief description of the discrete equations will be presented with the rationale behind the decisions made during the discretization process. To demonstrate that the dynamical core can simulate motion for a wide range of scales, the small-scale warm and cold bubble test cases, and the evolution of extratropical cyclogenesis on a beta-plane are simulated. The results show that the dynamical core behaves similar to an anelastic and quasi-hydrostatic cores in simulating small and large scales, respectively.