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A three-dimensional discontinuous Galerkin dynamical core for nonhydrostatic atmospheric simulations on the sphere

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Authors A discontinuous Galerkin nonhydrostatic atmospheric model is presented for two- and three-dimensional simulations. There is a wide range of timescales to be dealt with. To do so, two different implicit/explicit time discretizations are implemented. The vertical discretization is adapted to ensure the balance between pressure and gravity effects, preventing the generation of spurious oscillations. A stability analysis demonstrates that the use of this modified scheme discards the instability associated with the usual discretization.

The equations are solved on the sphere, based on a stereographic projection with a high-order mapping of the elements from the stereographic space to the sphere. The projection is slightly modified, in order to take into account the domain depth without introducing any approximation about the aspect ratio. In a discontinuous Galerkin framework, the elements alongside the equator are exactly represented using a non-polynomial geometry, in order to avoid the numerical issues associated with the seam joining the two hemispheres.

The resulting model is validated on idealized three-dimensional atmospheric test cases on the sphere, demonstrating the good convergence properties of the scheme, its mass conservation, and its good behavior in terms of accuracy and low numerical dissipation. Runtimes resulting from strong and weak scaling experiments demonstrate the attractivity of the discontinuous Galerkin method with implicit/explicit time integration for large scale atmospheric flows. A simulation is performed on variable resolution unstructured grids, producing accurate results despite a substantial reduction of the number of elements. Simulations of idealized tropical cyclones are considered as a first step towards realistic forecasts.