Robust discontinuous Galerkin models for atmospheric dynamics using non-conforming mesh refinement

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Abstract

Atmospheric flows feature phenomena on a very wide range of spatial scales that interact with each other. Many strongly localized features, such as complex orography, can only be modelled correctly if a very high spatial resolution is employed, especially in the lower troposphere, while larger scale features such as high/low pressure systems and stratospheric flows can be adequately resolved on much coarser meshes. Therefore, NWP is an apparently ideal framework for adaptive numerical approaches. However, mesh adaptation strategies have only slowly found their way into the NWP literature, due to limitations of earlier numerical methods, concerns about the accuracy of the representation of atmospheric wave phenomena for variable resolution meshes, and the complexity of an efficient parallel implementation for non-uniform or adaptive meshes.

We showcase results using an IMplicit-EXplicit Discontinuous Galerkin (IMEX-DG) method with local mesh refinement capabilities applied to Cartesian benchmarks for compressible atmospheric flows over both idealized and real orography. The scheme has been implemented in the framework of the deal.II library. We show that simulations with adaptive meshes around both idealised and real orographic profiles can increase the accuracy of the local flow description without affecting the larger scales, thereby significantly reducing the overall number of degrees of freedom compared to uniform mesh simulations. Moreover, we assess the impact of using curved boundary elements, whereby the representation of the boundary is based on the local polynomial interpolation of the curved geometry. Finally we demonstrate the good scaling properties of the method in both uniform and adaptive configurations and discuss ideas on how to improve solver efficiency with a view to runs in spherical geometry.

Keywords: discontinuous Galerkin methods, flows over orography, lee waves, non, conforming meshes, high, order mapping

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