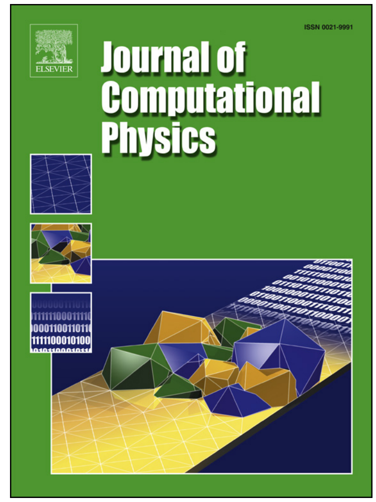

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A High Order Characteristic Discontinuous Galerkin Scheme for Advection on Unstructured Meshes

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Abstract

A new *characteristic discontinuous Galerkin* (CDG) advection scheme is presented. In contrast to standard discontinuous Galerkin schemes, the test functions themselves follow characteristics in order to ensure conservation and the edges of each element are also traced backwards along characteristics in order to create a *swept region*, which is integrated in order to determine the mass flux across the edge. Both the accuracy and performance of the scheme are greatly improved by the use of large Courant-Friedrichs-Lewy numbers for a shear flow test case and the scheme is shown to scale sublinearly with the number of tracers being advected, outperforming a standard flux corrected transport scheme for 10 or more tracers with a linear basis. Moreover the CDG scheme may be run to arbitrarily high order spatial accuracy and on unstructured grids, and is shown to give the correct order of error convergence for piecewise linear and quadratic bases on regular quadrilateral and hexahedral planar grids. Using a modal Taylor series basis, the scheme may be made monotone while preserving conservation with the use of a standard slope limiter, although this reduces the formal accuracy of the scheme to first order. The second order scheme is roughly as accurate as the incremental remap scheme with nonlocal gradient reconstruction at half the horizontal resolution. The scheme is being developed for implementation within the Model for Prediction Across Scales (MPAS) Ocean model, an unstructured grid finite volume ocean model.

Keywords: Discontinuous Galerkin, Advection equation, High order advection, Lagrangian characteristics, Unstructured grid

1. Introduction

Tracer advection constitutes a large portion of the compute time for modern global climate models, due to the large number of chemical and hydrometeor species that must be accounted for. For physical consistency, the advection of tracers must be conservative while being as numerically accurate and computationally efficient as possible. The

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