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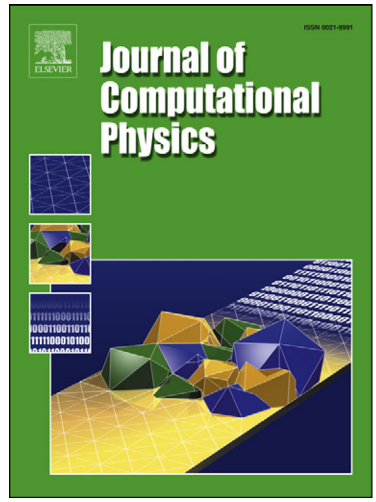

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Multi-Dimensional Finite-Volume Scheme for Hyperbolic Conservation Laws on Three-Dimensional Solution-Adaptive Cubed-Sphere Grids

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Abstract

A scalable parallel and block-adaptive cubed-sphere grid simulation framework is described for solution of hyperbolic conservation laws in domains between two concentric spheres. In particular, the Euler and ideal magnetohydrodynamics (MHD) equations are considered. Compared to existing cubed-sphere grid algorithms, a novelty of the proposed approach involves the use of a fully multi-dimensional finite-volume method. This leads to important advantages when the treatment of boundaries and corners of the six sectors of the cubed-sphere grid is considered. Most existing finite-volume approaches use dimension-by-dimension differencing and require special interpolation or reconstruction procedures at ghost cells adjacent to sector boundaries in order to achieve an order of solution accuracy higher than unity. In contrast, in our multi-dimensional approach, solution blocks adjacent to sector boundaries can directly use physical cells from the adjacent sector as ghost cells while maintaining uniform second-order accuracy. This leads to important advantages in terms of simplicity of implementation for both parallelism and adaptivity at sector boundaries. Crucial elements of the proposed scheme are: unstructured connectivity of the six grid root blocks that correspond to the six sectors of the cubed-sphere grid, multi-dimensional k-exact reconstruction that automatically takes into account information from neighbouring cells isotropically and is able to automatically handle varying stencil size, and adaptive division of the solution blocks into smaller blocks of varying spatial resolution that are all treated exactly equally for inter-block communication, flux calculation, adaptivity and parallelization. The proposed approach is fully three-dimensional, whereas previous studies on cubed-sphere grids have been either restricted to two-dimensional geometries on the sphere or have grids and solution methods with limited capabilities in the third dimension in terms of adaptivity and parallelism. Numerical results for several problems, including systematic grid convergence studies, MHD bow-shock flows, and global modelling of solar wind flow are discussed to demonstrate the

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