

A Parallel AMR Implementation of The Discrete Ordinates Method for Radiation Transport

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Efficient implementation of the discrete ordinates method using block-structured adaptive mesh refinement presents both opportunities and challenges. The opportunities derive not only from the standard efficiencies of regular meshes, but also from the use of transport sweeps, the most natural building blocks of discrete ordinates solvers. In a transport sweep solutions are updated using an upwind discretization, and computation moves through the grid following the direction of each ray (ordinate) of the angular discretization. On rectangular meshes, including Cartesian, 2D axisymmetric, and 1D spherical coordinate systems, this is a straightforward progression beginning at the upstream corner of the grid—an advantage that is preserved with structured AMR. On curvilinear or unstructured meshes, however, sweeping becomes more difficult, requiring sorting of grid cells and in some cases the breaking of dependency loops.

The challenges are at least threefold. First, the sweeping algorithm must be modified to take the adaptive mesh layout into account. On single refinement levels in 2D this is a simple matter of sweeping grids in a particular order, but in 3D a simple ordering is not always possible. In problems involving multiple levels communication across coarse-fine interfaces must also be properly defined. Second, in a spatially-decomposed parallel calculation, not only must processors communicate interface data with each other, the entire algorithm must be carefully arranged to prevent the sequential nature of each transport sweep from wrecking the parallelism of the global computation. Third, transport sweeps alone often do not yield adequate convergence rates, so acceleration techniques are required. While this fact is independent of the choice of mesh, the use of AMR can influence the implementation and efficiency of the convergence acceleration algorithms.

I will discuss the above issues, and also the coupling between radiative transport and the fluid energy equation, the integration of transport solutions into the AMR timestepping scheme, and conservation of energy in both an instantaneous and a time-dependent sense. I will present example calculations and will contrast the transport solver with a radiation diffusion solver implemented within the same algorithmic framework.