New continuity-based velocity interpolation scheme for staggered grids

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In the marker-in-cell method combined with staggered finite differences, Lagrangian markers carrying information on material properties are advected with the velocity field interpolated from the staggered Eulerian velocity grid. With existing schemes, velocity interpolation from the grid points to markers violates (to some extent) mass conservation requirement that causes excess convergence/divergence of markers and opening marker gaps after significant amount of advection. This effect is especially well visible in case of diagonal simple shear deformation along planes that are oriented at 45 degrees to the grid and marker circulation through grid corners.

Here, we present a new second order velocity interpolation scheme that guarantees exact interpolation of normal strain rate components from pressure nodes (i.e. from the locations where these components are defined by solving of the mass conservation equation). This new interpolation scheme is thus applicable to both compressible and incompressible flow and is trivially expendable to 3D and to non-regular staggered grids.

Performed tests show that, compared to other velocity interpolation approaches, the new scheme has superior performance in preserving continuity of the marker field during the long-term advection including the diagonal simple shear deformation and marker circulation through grid corners. We showcase a performance-oriented implementation of the new scheme using Julia language’s shared memory parallelisation features. The Julia implementation of the new advection schemes further augments the ParallelStencil.jl related application collection with advection routines.