

The Numerical Advection of Discontinuous Quantities in Geophysical Flows Using Particle Level Sets

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Advection a major process that commonly acts on various scales in nature (core formation, mantle convective stirring, multi-phase flows in magma chambers, salt diapirism ...). While this process can be modeled numerically by solving conservation equations, various geodynamic scenarios involve advection of quantities with sharp discontinuities. Unfortunately, in these cases modeling numerically pure advection becomes very challenging, in particular because sharp discontinuities lead to numerical instabilities, which prevent the local use of high order numerical schemes.

Several approaches have been used in computational geodynamics in order to overcome this difficulty, with variable amounts of success. Despite the use of correcting filters or non-oscillatory, shock-preserving schemes, Eulerian (fixed grid) techniques generally suffer from artificial numerical diffusion. Lagrangian approaches (dynamic grids or particles) tend to be more popular in computational geodynamics because they are not prone to excessive numerical diffusion. However, these approaches are generally computationally expensive, especially in 3D, and can suffer from spurious statistical noise.

As an alternative to these aforementioned approaches, we have applied the relatively recent Particle Level set method for modeling advection of quantities with the presence of sharp discontinuities. We have tested this improved method, which combines the best of Eulerian and Lagrangian approaches, against well known benchmarks and classical 2D and 3D Geodynamic flows.

In each case the Particle Level Set method accuracy equals or is better than other Eulerian and Lagrangian methods, and leads to significantly smaller computational cost, in particular in three-dimensional flows, where the reduction of computational time for modeling advection processes is most needed.