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A particle-mesh algorithm for advection-reaction-diffusion equations with applications to plankton modeling

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The interplay of advection, reaction and diffusion terms in ADR equations is a rather difficult one to be modeled numerically. The kind of spurious oscillations that is usually harmless for non-reacting scalars is often amplified without bounds by reaction terms. Furthermore, in most biogeochimical applications, such as mesoscale or global-scale plankton modeling, the diffusive fluxes may be smaller than the numerical ones.

Inspired by the particle-mesh methods used by cosmologists, we propose to discretize on a grid only the diffusive term of the equation, and solve the advection-reaction terms as ordinary differential equations along the characteristic lines. Diffusion happens by letting the concentration field carried by each particle to relax towards the diffusive field known on the grid, without redistributing the particles.

This method, in the limit of vanishing diffusivity and for a fixed mesh size, recovers the advection-reaction solution with no numerical diffusion. We show some example numerical solutions of the ADR equations stemming from a simple predator-prey model.